SD
11
.R4

FOREST SERVICE ENGINEERING REQUIREMENTS FOR WATER STORAGE AND TRANSMISSION PROJECTS

(REVISED JANUARY 18, 1983)

THIS DOCUMENT IS INTENDED TO OFFER TECHNICAL AND ADMINISTRATIVE ORIENTATION TO POTENTIAL PERMITTEES OF DAM AND CANAL PROJECTS LOCATED ON NATIONAL FOREST LANDS.

ENGINEERING
REGION 4

Property of
National FS Library
USDA Forest Service
240 W Prospect Rd
Fort Collins CO 80526

FOREST SERVICE ENGINEERING REQUIREMENTS FOR WATER STORAGE AND TRANSMISSION PROJECTS
(Revised 1/83)

Introduction. The following information has been compiled from Forest Service regulations and requirements for designs and plans of dams. The Forest Service has classified dams into four classes defined as follows:

1. Class A Projects. These include:

a. Dams that are 100 feet or more high or impound 50,000 acre-feet or more of water.

b. Channels, flumes, and tunnels that have a design capacity of 1,000 cubic feet or more per second (cfs).

2. Class B Projects. These include:

a. Dams that are 40 feet or more, but less than 100 feet, high or impound 1,000 or more, but less than 50,000, acre-feet of water.

b. Channels, flumes, and tunnels that have a design capacity of 100 or more, but less than 1,000, cubic feet per second (cfs).

3. Class C Projects. These include:

a. Dams that are 25 or more, but less than 40, feet high or impound 50 or more, but less than 1,000, acre-feet of water.

b. Channels, flumes, and tunnels that have a design capacity of 10 or more, but less than 100, cubic feet per second (cfs).

4. Class D Projects. These include:

a. Dams that are less than 25 feet high and impound less than 50 acre-feet of water.

b. Channels and flumes that have a design capacity less than 10 cubic feet per second.

Dam height is defined as the maximum vertical dimension of the dam measured through its centerline. The core trench or cutoff wall is not included in the height of dams founded on unconsolidated materials.

Storage capacity is defined as the quantity of water which can be stored between the elevation of the crest of the spillway or other uncontrolled outlet and the minimum elevation to which the reservoir surface can be lowered through the outlet pipe. If there is no outlet pipe, the storage capacity is the quantity of water below the crest of the spillway or other uncontrolled outlet. The following broad hazard ratings will concern dam design criteria:

1. High Hazard. Applies to structures where failure will result in loss of life.

2. Moderate Hazard. Applies to structures built in areas where failure would result in serious damage to lands or improvements administered by the Forest Service or in areas where failure may cause damage to private lands and improvements, dwellings, industrial or commercial buildings, or damage to facilities or service of important public utilities, highways, or railroads.

3. Low Hazard. Applies to structures built in undeveloped areas where failure would result in minor damage limited to lands administered by the Forest Service or roads, trails, and other improvements on these lands. Assignment of a low hazard rating assumes that downstream occupancy or development can be administratively controlled during the life of the dam to preserve its low hazard rating.

Examples of application of this system could be:

1. Class A High Hazard. A large dam located directly upstream of a town, city, or human use area.

2. Class A Low Hazard. A large dam located in a remote area unused by humans.

3. Class D High Hazard. A small dam located directly upstream of a heavy human use area.

Any combination is feasible, given site specific conditions. Determination of class-rating may require expert consultation in order to accurately access hazard potential. A dam breach analysis for proposed structures may be utilized to determine flood plains and potential hazard.

State laws in Region 4 require acquisition of a permit for storing or diverting water. Construction of a water project will not be commenced until such a permit is obtained. The approval by the State Engineer is required by State law when any of the following criteria are exceeded:

State	Height	Storage Capacity
California	25 feet	50 acre-feet
Idaho	10 feet	100 acre-feet
Nevada	10 feet	10 acre-feet
Utah	all heights	20 acre-feet
Wyoming	5 feet running stream, 10 feet other	----------

No technical approval for projects will be given until the applicant can show approval of the plans and specifications by the State Engineer or related office. Applicants are encouraged, however, to submit preliminary plans to the Forest Service for review and comment before final plans are drawn. Approval of drawings and specifications by the State Government Agency does not assure Forest Service approval.

Terms and Definitions

Conservation Pool. That part of the reservoir volume allotted to the storage of water for beneficial purposes other than flood control.

Core. The inner, usually relatively impervious, zone of an earth dam or earth-rock dam.

Core Trench (or Cutoff Trench). A trench excavated in the foundation and back-filled with relatively impervious material to prevent seepage of water under an embankment.

Dam Base Width. The width of the dam at its contact with the normal flood plain.

Dam Centerline. The longitudinal axis of the top of the dam.

Dam Height. The maximum vertical dimension of the dam--measured through the dam centerline--above the elevation of the natural streambed.

Dam Length. The length of the dam centerline between the abutments.

Dam Top Width. The top dimension measured normal to the dam centerline.

Design Reservoir Stage. The highest elevation of the water surface in the reservoir determined by routing the emergency spillway design hydrograph through the reservoir.

Drainage Area. The surface area of a watershed that contributes runoff into a reservoir.

Drawdown. A lowering of the reservoir stage.

Emergency Spillway. The spillway designed to convey water in excess of that impounded for beneficial uses.

Emergency Spillway Design Discharge. The peak flow determined by routing the emergency spillway design hydrograph through the reservoir-spillway system.

Emergency Spillway Hydrograph. The hydrograph used as a basis for the hydraulic design of the emergency spillway.

Flood Pool, or Retarding Pool. That part of the reservoir volume allotted to the temporary storage of floodwater. Its upper limit is the minimum elevation of the crest of the emergency spillway.

Flood Pool Hydrograph. The hydrograph is used as a basis for proportioning the flood-pool spillway-retarding pool system, and establishing the lowest crest elevation of the emergency spillway for a flood-control dam.

Flood Pool Spillway. The spillway designed to convey the water from the retarding pool at predetermined controlled release rates.

Freeboard. The difference between the design reservoir stage and the elevation of the lowest point on the top of the dam.

Freeboard Hydrograph. The hydrograph used to determine the required minimum elevation of the top of the dam.

Freeboard Reservoir Stage. The highest elevation of the water surface in the reservoir determined by routing the freeboard hydrograph through the reservoir-spillway system.

Sediment Pool. That part of the reservoir volume allotted to the storage of sediment.

Sediment Pool Elevation. The elevation of the surface of the sediment pool at the dam.

Shell. The outer, usually relatively pervious, zone of an earth dam or earth-rock dam.

Project Investigation. The project investigation by the proponent to the degree warranted by the size, cost, and hazard potential of the project shall be conducted as outlined in the Handbook on Design of Small Dams, Bureau of Reclamation, which has been adopted for Forest Service use, and Forest Service Manual 7500. The investigations shall also determine whether State law requires acquisition of a water right for the project and the quantity of water available for appropriation for the intended use. The investigation shall also include a preliminary cost estimate sufficiently accurate to determine if the project is economically justifiable. An administrative review will be made of all projects to the degree warranted by the size, cost, and potential impact of the project upon Forest Service administered land and resources.

Scheduling. To efficiently accomplish the design of a structure, or system of structures, it is necessary to schedule the work in a manner that will allow the design to be developed in an orderly progression.

The design schedule may be divided into four main phases:

1. Phase I, feasibility studies.
2. Phase II, collection and evaluation of data.
3. Phase III, preliminary design.
4. Phase IV, final design.

Although there is some overlapping of the work in the various phases, the end of each phase provides a logical opportunity for effective review. Complex projects may be further divided into subphases for control purposes. Simple projects may not require separate review of each phase. The scope of work normally done in each phase of design is summarized in the following paragraphs.

Phase I, Feasibility Studies. In the planning stage, studies must be made to determine the feasibility of installing the proposed project in the given watershed.

Reports of feasibility studies may vary from memorandum-type reports to formal, comprehensive reports, depending on the type and class of project. Watershed work plans developed for watershed protection and flood prevention projects under Public Law 566 are examples of formal feasibility studies.

Much of the information gathered in a feasibility study may be obtained from map studies, both topographic and geologic, site reconnaissance, and watershed reconnaissance. However, such reconnaissance investigations usually must be supplemented by field surveys, hydrologic studies, economic studies, and subsurface investigations.

1. Feasibility studies must be made in the detail required to determine, with reasonable assurance, that:

a. The desired functional objectives of the project can be attained.

b. The construction of the project is physically practicable.

c. The benefits derived from the project will exceed the cost of installation, operation, and maintenance.

2. Required scope and intensity of the studies, surveys, and investigations varies with:

a. The complexity of the proposed system of structures.

b. The geologic structure of the watershed.

c. The nature of the benefited areas.

d. The importance of the project in terms of size, cost, or impact on other programs.

Phase II, Collection and Evaluation of Design Data. Sufficient basic data must be collected by means of surface reconnaissance, surveys, subsurface investigations, materials testing, and hydrologic studies to furnish an adequate basis for design. The data collected must be sufficiently accurate to allow reasonable confidence in the assumptions and approximations that must be made to establish and apply design criteria.

Some data collection occurs in Phase I. Usually, the quantity of data collected in Phase I is not adequate for use as a basis for final design. However, it should be adequate for use in planning design surveys and investigations executed in Phase II. To avoid duplication of effort, perform Phase I surveys and investigations to the same standards prescribed for design surveys and investigations whenever possible.

It is often found necessary to obtain supplementary data after the design has progressed into Phases III and IV. When such needs arise, the designer (or reviewer) should promptly notify the office concerned.

The validity of the data furnished will vary with the scope and competence of the data-collection program. The criteria given in FSM 7522 and 7523 establish acceptable minimum standards for surveys and investigations. Complex site conditions or special job requirements may justify the requirement of higher standards.

In any case, the designer or reviewer must evaluate all of the basic data and assess their suitability for use as a basis for design. The data submitted must be of sufficient quantity and quality, consistent with the type and class of project, to present all pertinent site conditions and hydrologic conditions.

In making this evaluation, the designer, in collaboration with appropriate specialists, must be guided by published instructions and criteria and by a general knowledge of good design practice.

Omissions, discrepancies, and inadequacies must be reported to the engineer responsible for data collection as soon as possible. Such reports should contain suggestions for supplementary investigations or other corrective actions to be taken to secure adequate data.

Coordination with other staff specialists is essential to the evaluation. Early collaboration of proponents, designers, reviewers, materials engineers, and the field staff often will reduce the evaluation to a final check of design data.

Phase III, Preliminary Design. Preliminary design consists of the development of the general features of the structural improvements.

1. Preliminary designs include the selection of:

   a. The most suitable type of structures.

   b. The optimum layout and arrangement of the elements of the structural system.

   c. The types and locations of appurtenant mechanical equipment.

   d. The most feasible power source, if applicable.

2. The hydraulic design should be sufficiently refined to permit the selections of:

   a. The alignment grades, and cross-sections of channels.

   b. The critical elevations, general dimensions, and capacities of all water-control structures and equipment in the system.

3. Structural dimensions should be sufficiently refined to allow preparation of reasonable estimates of quantities of materials. Only those structural details considered essential to the study of alternate designs should be developed.

Phase IV, Final Design. Final design consists of:

1. The checking of the adequacy of the surveys and investigations and the accuracy of the layout chosen in the preliminary design.

2. The detailed refinement of the layout and hydraulic design.

3. The completion of the structural design.

4. The preparation of the construction drawings, specifications, bid schedules, engineer's estimate, and construction schedule.

5. Preparation of the final design summary.

Design Review. A design review and approval for drawings, specifications, engineering and geologic reports, and supporting data is required.

The review and approval must be performed by personnel not directly involved in the design of the project. All Class A high hazard dams will receive an independent design review prior to design approval. For all other structures a determination will be made on the necessity for an independent design review. Such evaluation will be documented in the routine design review and approval process for the dam.

For Forest Service projects, the design review will be made either by personnel from within the agency, outside consultants, or a combination of the two. For projects authorized by special-use permits or other authority, the permittee shall be required to provide design review by an independent panel of consultants.

While a project is under construction, both design and construction personnel shall maintain close coordination to assure that the intent of the project design is carried out, and that new information acquired during construction is incorporated into the design.

Where an independent design review was determined necessary, the independent review team shall inspect the project at all critical points during construction.

Design Surveys. Expansion of this section sets forth general criteria for the conduct of field surveys for water-storage and -transmission works and for the preparation of topographic maps from data produced from such surveys.

Instrumentation. Depending on the size of dam and site, specific foundation conditions and dam design, and materials, consideration should be given to installation of a designed instrumentation system to observe changing conditions in the foundation, in the dam, and in the abutments during construction and project operation. As a minimum, a system of foundation and embankment instruments will be provided for high hazard Class A dams to monitor performance.

Emergency Procedures

Emergency Preparedness Plan. Maintain an emergency preparedness plan for any dam where loss of life or serious public damage could occur in the event of failure. When possible, the plan should involve State and local authorities responsible for civil preparedness. The emergency plan should include warning plans as well as emergency procedures to be taken if conditions occur which could be potentially dangerous to the safety of the dam. Pertinent features that must be included in the plan are:

Actions to prevent or reduce consequences of failures, public notification plan, assignment of responsibility for evacuation of people from downstream threatened areas, and designation of the individual responsible for invoking the plan.

Forest Service Dams. The Forest Supervisor prepares the emergency preparedness plan.

Other Dams. The owner or permittee prepares the emergency preparedness plan.

Notes and Records. Notes and records should be kept in bound survey notebooks of standard type.

Precision of Surveys

1. Horizontal Control. Transit traverses should be of such precision that:

a. the linear error of closure does not exceed 1 in 3,000, and

b. the angular error of closure (in minutes) does not exceed the square root of the number of angles in the traverse.

2. Vertical Control. Bench-level traverses should be of such precision that the error of closure in feet does not exceed plus or minus 0.05 times the square root of the length of the traverse in miles. The elevations of points on profiles and cross-sections should be determined and recorded to the nearest 0.1 foot.

Monuments and References. During the design survey, the alignment and layout control points should be marked and referenced so that they can be readily reestablished. Unless otherwise approved, control points should be marked by hubs buried at least 18 inches below the ground surface and referenced by guard stakes set at the ground surface. The location and description of all control points should be recorded in the notes. The markings on guard stakes should include:

1. The distance to the control point.

2. The line to the control point.

3. The station of the control point. Control points that must be used during or after construction should be set in such a manner that they will not be made useless by construction operations.

Bench Marks. During the design survey, permanent bench marks should be established for use during the construction of the works. Unless otherwise approved, permanent bench marks should consist of bronze pincer caps set in concrete. The location, description, and elevation of each bench mark should be recorded in the notes.

Topographic Maps. The requirements for precision of maps are shown in the following Table 1.

Table 1 -- Precision of Topographic Maps for Design Purposes

Map Characteristic	Type of Topographic Map			
	Structure Site	Floodway (Strip Map)	Reservoir	Borrow Area
1. Average error (in feet) in scaled dimensions shall not exceed:	0.025 x scale*	0.05 x scale*	0.05 x scale*	0.075 x scale*
2. Percentage error in scaled areas shall not exceed:	0.05 x scale*	0.10 x scale*	0.10 x scale*	0.15 x scale
3. Average error (in feet) in elevation shall not exceed:	1	1	2	2
4. Of points chosen at random, the percentage whose error in elevation exceeds one-half the specified contour interval shall not exceed:	5%	10%	15%	15%
5. For any profile, the ratio of the length of map profile that lies above the ground profile to the length of map profile that lies below the ground profile shall lie between:	1/2 and 2	1/3 and 3	1/3 and 3	1/4 and 4

*Expressed as feet per inch.

Subsurface Investigations, Sampling, and Soil Testing. This section sets forth the general requirements for accomplishing subsurface investigations, sampling, and soil testing for water-storage and -transmission facilities.

Standard Definitions and Terms. Terms relating to geology and soil mechanics used in correspondence, records, and reports relating to water-storage and -transmission works should conform to the definitions contained in: (1) Glossary of Geology and Related Sciences, American Geological Institute; (2) Definitions Relating to Soil Mechanics, ASTM Designation D653; and with the following additional definitions:

1. Rough Profile. A soil or rock profile showing the depths to principal strata and depths to the free groundwater level, in cases where the exploration extends below groundwater levels.

2. Detailed Profile. A soil or rock profile showing not only the major strata, but also the dip and strike of the strata, thin strata, seams, faults, lenses, shear planes, water-bearing strata, any pertinent piezometric pressures at various depths, and other details crucial to the purpose of the investigation.

3. Bedrock Profile. A profile showing only surface elevations and depths to rock, or, in some cases, to strata of exceptional bearing capacity, such as hardpan, hard clay, or very dense sands and gravels.

4. Significant Depth. The vertical distance below the ground surface within which either the:

a. Loads applied to the foundation may be expected to alter the state of stress in the foundation materials enough to produce critical shear strains or to cause significant increments of settlement by compression of the foundation.

b. Permeability, or piezometric characteristics, of the foundation profile may be expected to influence the stability or functional adequacy of the proposed structure.

5. Representative Samples. Samples of soil or rock, either disturbed or undisturbed, selected and recovered in such a manner as to ensure that they indicate the true nature of the material in the zone under consideration to the extent required to determine the characteristics and properties pertinent to the purpose of the investigation.

Resolution of Conflicting Terms. When a term is used for which there are conflicting definitions in the cited references, the user of the term should cite the reference whose defintion of the term connotes the intended meaning.

Slope of Investigations. Determine the soil profile--and, when required, the rock profile--to significant depths to the extent and in the detail required to obtain data of the kinds and qualities and in the quantities appropriate to the purpose of the investigation. Subject to Forest Service approval, the proponent of the design should determine the depth and extent of borings, the

number and kinds of samples to be recovered, and the number and kinds of field and laboratory tests to be performed, except that the following minimum requirements should be observed:

1. Investigations for High-Hazard Dams, Moderate-Hazard Dams, and Low-Hazard Dams Over 25 Feet High. These investigations should be adequate to determine:

a. Detailed profiles of the foundation throughout the base area of the dam, abutments, and reservoir.

b. The sheer strength of materials to a depth equal to half the height of the proposed embankment (or concrete or masonry gravity dam), unless bedrock is encountered at lesser depth.

c. The compressibility of materials to a depth equal to one and a half times the height of the proposed embankment, or equal to the height of a concrete or masonry gravity dam, unless bedrock is encountered or the compressible zone terminates at lesser depth.

d. The relative permeability of materials to a depth at which a significant impervious stratum is encountered or other significant depth.

e. In potential mining areas, the extent of subordination of mining rights required to ensure the stability of dams and spillways.

f. In mined areas, the extent of structural supports required to be installed in mine workings to ensure the stability of dams and spillways.

g. The character of materials proposed for use as fill materials or aggregates for concrete.

2. Investigations for Floodway, Irrigation, or Drainage Channels.

a. Investigations should include sufficient borings (or pits) and tests to indicate:

(1) The nature and extent of the types of material that occur along the channel alignment.

(2) The suitability of the materials for use as fill.

(3) The groundwater conditions existing, within the depth of boring, at the time of the investigation.

b. Unless bedrock is encountered at lesser depths, test holes should extend below the proposed channel bottom to a depth at least equal either:

(1) To one-half of the horizontal length of the proposed side slope.

(2) To the proposed bottom width, whichever is less.

3. Number of Test Holes. Frequency of sampling and type of sampling should be adequate to ensure the recovery of representative samples.

Plan of Operations. Prior to the start of detailed subsurface investigations, the proponent should submit to the Forest Supervisor three copies of a memorandum report outlining the plan for doing the work. The plan should be based on a physical reconnaissance of the site and consideration of data included in reports of preliminary investigations and surveys or general area studies. The report should be of such scope as to show clearly that the work to be done will furnish the needed data. It should show:

1. The proposed drilling methods, geophysical methods, sampling methods, and equipment.

2. The approximate locations of proposed borings and test pits.

3. The approximate locations of axes of proposed geophysical soundings.

4. The kinds and approximate numbers of proposed field and laboratory tests.

5. The scope of the proposed geologic reconnaissance.

Operating Procedures

Identification of Soils. Soils should be identified and classified by means of the unified classification system as prescribed in ASTM designation D2487.

Exploratory Methods. The effectiveness of exploratory methods should be generally evaluated as follows:

1. Wash borings, probings, or unverified geophysical soundings should be considered adequate only for determining rough bedrock profiles.

2. Auger borings, except large-diameter bucket augers, or small-diameter, less than two inches, split-spoon borings, with or without supplemental geophysical soundings, should be considered adequate only for determining bedrock profiles or rough soil profiles. Continuous flight augers should not be used for logging or sampling.

3. Core borings, including pushtube and piston samplings, over 2 inches in diameter, test pits, test trenches, or inspection holes are needed to determine detailed soil profiles. Large-diameter bucket-auger borings may be considered adequate for this purpose in very coarse or very mixed materials. A bedrock profile determined by borings, probings, or soundings should be verified by means of test pits, trenches, or large diameter inspection holes:

a. When the depth to rock is less than 20 feet and the purpose of determining the bedrock profile is to classify major quantities of excavation.

b. Along the axis of feasible locations for drop-inlet spillways or other outlet works to be located in or under an embankment.

c. At any point, or in any zone, where the founding of a structural element on rock is crucial to the stability of functional integrity of the structure.

d. When needed to estimate grouting or dental concreting requirements.

Soil-Sampling and Field-Testing Methods. Soil-sampling methods and field-testing methods should conform to the requirements of either the standard or tentative methods of the American Society for Testing and Materials (ASTM). Methods for tests not covered by ASTM standards (or tentative) methods should conform to accepted engineering practice.

Laboratory-Testing Methods. Laboratory-testing methods should conform to the requirements of the standard (or tentative) methods of the ASTM. Methods for tests not covered by ASTM standard (or tentative) methods should conform to accepted engineering practice.

Logging. A log of each test hole or geophysical sounding should be recorded. The format and content should be adequate to the purpose of the investigation in accordance with accepted engineering practice, as exemplified by Chapter 7 of "Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes," Hvorslev, Engineering Foundation, New York, New York.

Reports. Drawings prepared for reports should conform to the requirements of FSM 7524. Copies of drawings included in reports may be of reduced size. Reports should include:

1. Plans showing the location of all test holes.

2. Copies of logs of all test holes.

3. Results of all field tests and laboratory tests.

4. Plotted profiles and cross-sections as necessary to show subsurface conditions.

5. Narrative discussion of critical geological conditions or engineering problems disclosed by the investigation.

Safety and Cleanup Requirements

Protection of Excavations. Borings, test pits, and other excavations should be excavated, braced, and supported (or cased) to:

1. Safeguard the work and the workmen.

2. Provide that ground adjacent to the excavation will not slide or settle.

3. Prevent damage to adjacent works.

Permits should require the permittee to furnish, place, and later remove such supporting works as needed.

When drill holes, test pits, or other excavations must be left open at the end of a day's work, they must be provided with such plugs, covers, fences, barricades, lights, markers, or other protective or warning devices as are needed to prevent injury to humans or livestock.

When drill holes, test pits, or other excavations are left open for observation after completion of the work, they must be provided with such caps, covers, fences, markers, or other protective or warning devices as are needed to prevent injury to humans and livestock and to protect the remaining installations.

Cleanup. Unless otherwise approved by the Forest Supervisor, upon completion of the work at each site, the following actions must be taken:

1. Backfill all borings, test pits, and other excavations.

2. Except for approved access roads, restore the land surface to the original grades.

3. Remove from the site all scrap or abandoned equipment, materials, and supplies of any nature.

Engineering Drawings Standards. Expansion of this section sets forth drafting standards for engineering drawings for water-storage and -transmission projects.

Sheet Size. Drawing sheets should be of conventional size convenient for handling, reproduction, and review. All sheets in a single series and intended to be bound together should be of equal size and dimensions.

Media and Technique. Drawings may be in pencil or ink. All lines and lettering should be clear and sharp and of sufficient width and density to ensure clear reproduction of both contact prints and half-sized reductions. Lettering should be of simple, single-stroke characters either formed freehand, or by use of lettering guides, or typed.

Scales. Scales of drawings should be carefully selected to ensure clarity of details. The manner of reproducing copies must be fully considered in determining the scales to be used.

The minimum scale of structural layout sheets should be one-quarter of an inch equals one foot. The minimum scale for structural-detail sheets should be three-eighths of an inch equals one foot.

Drawings that may be reduced in size for inclusion in contracts should have graphic scales.

Detailing. Detailing of structural drawings for concrete structures should conform to the instructions contained in American Concrete Institute standard 315.

Notes. Notes on the drawings should be limited to those required for complete and accurate interpretation of the drawings and those required to supplement contract specifications. Except for standard notes that generally apply to all

drawings within a single series, each note should be placed on the drawing sheet to which it applies. All notes should be lettered in lower case and capitalized according to normal English usage.

Cover Sheet. Each series of construction drawings should be prefaced with a cover sheet showing:

1. The name of the project.

2. The location of the project.

3. The names of the sponsoring agencies, or other proponents.

4. An index of drawings.

5. Provision for necessary approval signatures.

6. When space permits, the location map.

Orientation of Views. The views required to be shown on the drawings should be oriented in the following manner:

1. Location Maps. Whenever possible, these should be oriented with the north direction at the top of the sheet. When such orientation is not feasible, the map should be oriented with the north direction at the left side of the sheet. North arrows should be placed on all maps.

2. Plans and Layout Drawings for Water-Control Structures, Channels, and Reservoirs. These should be so oriented that the direction of streamflow is toward the top or right side of the sheet. Arrows showing the direction of streamflow and the north direction should be provided.

3. Elevations and Vertical Sections. These, representing surfaces that are parallel to the direction of streamflow, should be so oriented that the upstream sides of the elevations or sections are toward the left side of the sheet. Elevations and vertical sections representing surfaces that are normal to the direction of streamflow should be so oriented that they appear to be viewed from upstream (looking downstream), unless the purpose of the view would be frustrated by such orientation. When nonconventional orientation must be used, either the true aspect of the section must be indicated by section identification, or the position of the observer must be stated in the title of the view, such as "Looking Upstream."

4. Structure Reference Lines. These, such as center lines, that are parallel to the direction of streamflow, should be stationed in such a manner that the station numbers increase in a downstream direction. Structure reference lines that are normal to the direction of streamflow should be stationed from left to right, when oriented by the convention in Item 3.

5. Floodways and Irrigation Channels. These should be stationed in such a manner that the station numbers increase in a downstream direction.

Design Records. Design records should be kept orderly and current to allow for efficient review at any stage. They must be complete and understandable, since they may form the basis for such later actions as:

1. Design changes required by construction exigencies.

2. Modification or addition of appurtenant works.

3. Investigations of structural deficiencies.

Computations, Notes, and Design Drawings. All notes, computations, drawings, sketches, and other data should be recorded neatly and organized in a manner that will allow copying and use in design summaries or memorandums with a minimum of editing. A binding margin 3/4-inch wide should be reserved at the left side of each sheet. Design drawings, diagrams, graphs, sketches, or other pictorial representations should be made a part of the computation files when the size and scale allow. Design drawings that must be drawn on larger-sized sheets and cannot be folded to computation-sheet size should be cited at the proper place in the computations in a manner that fully identifies the drawing and its file location.

Preliminary Design Summary. When a separate review of the preliminary design is required, a preliminary design summary should be prepared by the proponent. The preliminary design summary should contain all material necessary for a thorough engineering review and understanding of the proposed design including:

1. A narrative description of the project or project phase.

2. A summary of data used as a basis for design.

3. A summary of design criteria used.

4. Drawings and/or sketches sufficient to define all essential elements of the design.

5. A summary of alternate layouts and designs considered and a detailed description of the alternate chosen. The summary should clearly demonstrate the reasons for the choice.

6. Computations and design notes developed in the preparation of the preliminary design.

Design Memorandums. At any stage in the development of a design, it may be necessary to obtain the concurrence of the reviewing authority in the selection of alternate details or other matters affecting the development of specific elements of the design. In each case where this is found necessary, the proponent should prepare a design memorandum containing a full presentation of pertinent facts. Copies of pertinent computations, sketches, notes, and drawings that are necessary for complete review of the proposal should be included. Such memorandums should be incorporated into the final design summary.

Final Design Summary. Following the completion and approval of all design work, the proponent should prepare the final design summary that will become a permanent record for future reference. It should consolidate into one document the engineering information, computations, quantity estimates, and cost estimates from previously approved and corrected memorandums that are pertinent to the plans and specifications as approved:

1. Alternate designs or solutions that are considered in a preliminary design summary should not be included except where mention of alternates and reasons for selection are pertinent. Material already presented in a preliminary design summary should not be repeated.

2. Such drawings as are necessary for proper explanation of the subject matter should be included in the summary.

3. The summary should be sectionalized and indexed in a logical manner. The number of sections required will vary with the scope and complexity of the design.

Report to Accompany Drawing. An applicant desiring to construct a dam on National Forest land will prepare a report to accompany the drawings and specifications. This report shall give data for the applicable items in the following outline. If it is not obvious why an item is not applicable, reason for its omission should be given.

Report to Accompany Drawings

_____ Dam
(Name)

1. Location and Purpose:

   a. Location by legal description, county, state, and nearest city.

   b. Accessibility.

   c. Statement of primary purpose and any secondary purposes.

   d. Storage requirements for purposes listed and by whom established.

2. Location Where Water Will be Used.

3. Summary of Design:

   a. Storage capacity:

      (1) To spillway level: _____ acre-feet

      (2) Active: _____ acre-feet

      (3) Dead: _____ acre-feet

b. Spillway capacity: _____ cfs

(1) Emergency spillway capacity: _____ cfs

c. Outlet capacity (normal water surface elevation) _____ cfs

d. Power outlet capacity: _____ cfs

e. Top of dam elevation: _____ feet

f. Normal water surface elevation: _____ feet

g. Maximum water surface elevation: _____ feet

h. Minimum water surface elevation: _____ feet

i. Freeboard above maximum water surface: _____ feet

j. Maximum height of dam: _____ feet

k. Estimated cost of dam: $_____

l. Estimated cost per acre-foot (usable storage): $_____

m. Total estimated cost of project: $_____

n. Project Drawings: Drawing No. _____
No. of sheets _____
Surveyed by _____
Date of survey _____

4. Design Data:

a. Geological Report. Submit two copies of geological report with name and title of author.

b. Soils Analysis. Laboratory tests of foundation and borrow material will be required for all Class A, Class B, and Class C dams and high-hazard Class D dams where failure may cause loss of life. Field classification of foundation and borrow material will be required for other dams. Material shall be identified by the Unified Soil Classification symbols as determined by either field or laboratory methods. The method used to determine classification will be shown. If field determination is used, give name and qualifications of person making test. For laboratory analysis of material, submit certified copy of results of laboratory tests. Foundation investigations will include field permeability tests, in-place density tests, depth to ground water, classification of materials, sheer tests, and complete logs of test holes.

5. Hydraulic Data:

a. Spillway: Specify method of computing spillway capacity, show computations, and relate any assumptions made. Compute maximum spillway velocity at maximum water surface. Submit basic computations.

b. Outlet. Show method of computing maximum outlet capacity. Show the normal outlet discharge in cfs.

c. Diversion. See Canals and Ditches section. Plans and report requirements as outlined in that section shall be submitted for all diversion structures.

6. Hydrologic Data:

a. Append hydrographs.

b. Show computations for determining maximum probable flood.

c. Show method of computing maximum outflow used for spillway design.

d. Show mean annual runoff of drainage basin.

e. Provide a chart or table showing climatic conditions, such as mean and peak annual precipitation, maximum and minimum temperatures, etc.

f. Provide a chart showing tailwater curve.

g. Delineate drainage area above dam on map (show acreage).

h. Show comparison between maximum flow in natural channel without dam, and flow with maximum releases (spillway and/or outlet) from dam.

If the flow in channel with maximum releases from dam is greater, submit information as required in Section 5-c above.

7. Reservoir and Dam Site:

a. Locate and describe existing improvements (road, telephone line, etc.) affected and relocations required.

b. Geology (may be covered in geology report).

(1) Reservoir. Include general formation, factors relating to reservoir losses, contributory springs, and deleterious mineral salt deposits.

(2) Dam Site. Include nature of streambed and abutments.

c. Enumerate limitations to maximum reservoir high water lines.

d. Locate, describe, and define right-of-way or land ownership other than National Forest.

8. Dam:

a. Show estimated height of dam and explain features governing type of design used.

b. Give basis for determination of dimensions of cutoff trench or wall.

c. Stipulate grouting requirements, if anticipated.

9. Outlet Works:

a. Show type and estimated size of outlet structure, such as conduit, valve, intake box, and where located.

b. Give computations for computing number of antiseep collars.

10. Spillway:

a. List factors governing design and location, such as spillway width and capacity, wall heights, energy dissipators, bridge, cutoff walls, etc.

b. Specify type of lining.

c. If protection of spillway from debris is not provided, explain reason.

11. Construction:

a. Give expected date of start of construction.

b. Show estimated time to complete project.

c. Point out special requirements that may affect construction.

12. Water Rights. Show evidence of water right.

13. Possible Damage in Case of Failure:

a. Describe possible damage to natural channel.

b. Show potential for loss of life.

c. Estimate possible damage to roads, bridges, buildings, and other improvements.

d. List and locate existing and planned hydraulic structures, above or below dam on same drainage, which might affect or be affected by failure of the proposed structure.

e. Give hazard classification. (See Introduction for definition of hazard classes.)

14. Borrow Areas:

a. Show location of all proposed borrows.

b. Give computations for borrow area quantities. (Minimum acceptable quantity of borrow is 150 percent of material needed in each zone of earth embankment and required for riprap.)

Design and Construction Standards

Spillways. All dams shall have a spillway with ample capacity for the maximum design flood flow.

1. Freeboard. Freeboard is defined as the vertical distance from the crest of the dam to the reservoir surface during design-flood conditions. Minimum freeboard for earthfill and rockfill dams will be:

a. Low Hazard. Two feet if reservoir is less than one-fourth of a mile long; three feet if reservoir is over one-fourth of a mile long.

b. Moderate and High Hazard. Three feet, or as required by State law, whichever is greater.

Minimum freeboard for nonoverflow sections for concrete dams will be three feet. Zero freeboard is appropriate for low- or moderate-hazard structures with spillway passing the maximum probable flood flow.

2. Flashboards. Flashboards, by which the normal pool level is raised during those periods when the spillway is not in use for discharging floods, will not be included in the design of proposed projects. The objection to their use is the risk of human failure if they are to be manually operated, the uncertainty of automatic operation under hydrostatic head, and the sudden release of large volumes of water when they operate.

3. Design Capacity. Except for structures incorporating flood control storage, spillway capacity must be sufficient to pass the instantaneous peak of the design storm. The design storm frequency shall be not less than 0.01 for high-hazard structures and not less than 0.02 for other structures. Design storm frequency of 0.001 may be appropriate for many high-hazard National Forest structures. (0.01 = 100 year flood, 0.02 = 50 year flood, and 0.001 = 1,000 year flood.)

Acceptable methods for determining the design storm for a specific project will be defined or approved by an experienced hydrologist.

1. Hydrologic Criteria. Criteria for a specific project should be selected on the basis of careful consideration of the characteristics of the watershed.

Design hydrographs should be developed from streamflow records when the period of record is long enough to allow valid volume-duration-probability analyses. Hydrologic criteria for any specific project must be approved by an experienced

Forest Service hydrologist prior to completion of the preliminary design. Whenever possible, rainfall and streamflow data from the subject watershed should be used to check at least the following:

a. The runoff distribution (hydrograph shape).

b. Watershed retention loss characteristics (hydrologic soilcover complex and runoff curve numbers).

c. Base flow.

2. Direct Rainfall Runoff. When local streamflow records are used to develop design hydrographs, enough information should be submitted to show the scope and length of the record, the quality of the data, and the statistical significance of the frequency analysis.

Computation of runoff volumes should be based on assumption of at least average watershed soil moisture content (antecedent moisture condition II). The effects of anticipated land management activities that would increase runoff should be considered in the selection of runoff curve numbers.

When adequate local records are not available, hydrographs of direct rainfall runoff may be developed by the following methods:

a. By transposing streamflow data from other parts of the watershed or from nearby watersheds. Regional records must be adequate to allow valid volume-duration-probability analyses. The transposition must compensate for all variations in watershed characteristics.

b. By use of a hydrometerological method that, in the judgment of the Regional Engineer, is most appropriate to the watershed in question. Such methods are presented in:

(1) Chapter 21, Section 4, National Engineering Handbook, Soil Conservation Service, United States Department of Agriculture. See also FSH 3509.12, Handbook on Methods of Hydrologic Analysis.

(2) Chapter II and Appendix A, Design of Small Dams, Bureau of Reclamation, United States Department of the Interior.

3. Snowmelt Runoff. For a watershed where snow is likely to accumulate, the effects of snowmelt runoff should be estimated.

Procedures for developing hydrographs for snowmelt floods or rain-on-snow floods are rather complex and require specialized surveys and investigations. Manual EM 1110-2-1406, Corps of Engineers, United States Army, discusses these procedures in considerable detail. Such procedures should be applied in the design of important projects where the snowmelt contribution is likely to be a crucial design factor.

For small projects, the effects of snowmelt should be estimated on the basis of the best available local records of runoff or Weather Bureau Technical publication 50. In any case, the following criteria define the minimum values to be applied in the design:

$$S_{mc} = \frac{P_m (40 - T_m)}{2}$$

$$S_{mi} = \frac{P_m (40 - T_m)}{53.8}$$

Where: S_{mc} = Snowmelt runoff in cubic feet per second per square mile of drainage area.

S_{mi} = Snowmelt runoff in inches per day.

P_m = Average March precipitation in inches.

T_m = Average March temperature in degrees Fahrenheit.

4. Flood-Pool Hydrograph. The flood-pool hydrograph should include the direct runoff from rainfall of a frequency equal to the selected degree of flood protection plus either base flow or snowmelt runoff, whichever is greater. In arid regions, channel losses from influent streams may be deducted from direct rainfall runoff.

Sometimes the allowable frequency of use of the emergency spillway is less than the selected degree of flood protection. In such cases, an additional hydrograph, corresponding to direct runoff from rainfall of a frequency equal to the allowable frequency of use of the spillway, must be developed. For purposes of design flood-routing, such additional hydrographs should not be confused with flood-pool hydrograph (FSM 7532.23).

5. Emergency Spillway Hydrograph and Freeboard Hydrograph. When a hydrometeorological method is used, the peak flow and total inflow volume of each design hydrograph must not be less than those resulting from runoff corresponding to the amount of rainfall shown in the following Table 1. Base flow and snowmelt runoff need not be added. The effect of snowmelt runoff should be checked separately.

Table 1--Minimum Rainfall Criteria[1/]

Hazard Rating	6-hour Rainfall Amount[2/]	
	Emergency Spillway Hydrograph	Freeboard Hydrograph
Moderate	$P_{100}+0.12(PMP-P_{100})$	$P_{100}+0.40(PMP-P_{100})$
High	$P_{100}+0.26(PMP-P_{100})$	PMP[3/]

1/ Compatible with Soil Conservation Service standard drawings ES-1020, ES-1021, ES-1022, ES-1023, and ES-1024.

2/ From United States Weather Bureau Rainfall Frequency Atlas.

Where: P_{100} = 100-year frequency rainfall in inches.

PMP = Probable maximum rainfall in inches.

3/ In the Bureau of Reclamation method, use probable maximum point storm value.

Wherever possible, the design storm shall be based on streamflow records. If streamflow records are not available for the drainage area under consideration, streamflow records for nearby drainage areas should be examined. If nearby drainage areas are similar to the drainage area under consideration, the design storm may be determined from peak flows projected upstream or downstream to the drainage area size under consideration. If applicable streamflow records are not available, the design storm may be determined from precipitation records or from floodflow formulas based on accepted engineering practice in the area. If the design storm has been determined from recorded streamflow measurements, the spillway capacity may be modified by the effect of reservoir storage above the spillway crest. A design storm determined from precipitation records or floodflow formulas shall be checked by at least one other method.

Where no hazard to life is involved, spillway capacity may be adjusted to the extent justified by an economic analysis comparing the amortized saving in construction cost with the average annual cost of replacement or repair of damage over an evaluation period of 30 years. The economic analysis shall include the average annual cost of anticipated downstream land or channel damage attributable to the reduced spillway design capacity.

1. Erosion Protection. Spillways should be protected against damaging erosion by locating in erosion-resistant material, limiting velocities to erosion-safe values, providing energy-dissipating features, or by lining the channel.

2. Layout of Spillway. Straight alignment of spillway channels is recommended. Curvature or a centerline deflection angle is permissible, provided the design flow will be adequately accommodated. Such alignment change must not be coincident with channel width transition unless model tests verify the hydraulic adequacy of such design. Curvature may be introduced at the outlet of the exit channel at a point where the discharge will not impinge on the dam or on unprotected slopes.

The grade of the exit channel shall be sufficiently steep to ensure supercritical flow for all discharges equal to or greater than 25 percent of the design discharge used to determine the capacity of the spillway.

3. Spillway Protection. Provision must be made to prevent debris and logs from jamming the spillway entrance and choking the spillway passage. The SCS drop inlet structure satisfies this requirement. Protection is particularly important where tangent alignment is unfeasible or where the spillway is unable to pass debris and logs. A floating log boom on the reservoir across the approach to the spillway is an effective debris and log barrier. The boom is also an effective safety measure for persons who may be in danger of being swept down the spillway. For recreation impoundments, a log boom in deep water is a safety hazard. A float-cable barrier should be used for this situation.

4. Flood-Pool Spillway Capacity. For a flood-retarding dam, the flood-pool spillway should be large enough to empty the flood pool in 10 days or less. A smaller spillway may be used if it is needed to limit flood damage downstream from the dam or to comply with legal requirements. When a smaller spillway is used, measures must be provided to offset damage that may result from prolonged storage or prolonged outflow.

For the purpose of determining the time required to empty the flood-pool, the flow through auxiliary gated outlets will not be considered.

5. Emergency-Spillway Crest Elevation. The emergency-spillway crest must be not lower than the highest reservoir water surface elevation determined by routing the flood-pool hydrograph through the reservoir and flood-pool spillway. The routing of the flood-pool hydrograph will start from the elevation of the surface of the sediment pool or conservation pool, as applicable.

When other limitations are imposed, such as limiting the frequency of use of the emergency spillway, the crest must be set above the minimum elevation described above. This may be accomplished by use of supplemental hydrographs as described in FSM 7532.13.

6. Emergency-Spillway Capacity and Freeboard. The emergency spillway must be at least large enough to meet the greater of the following requirements:

a. It must be able to pass the freeboard discharge with zero freeboard.

b. It must be able to pass the design discharge with a freeboard equal to at least the estimated maximum wave height that could be generated by wind.

For a reservoir without a flood-pool, the routings of the emergency spillway hydrograph and the freeboard hydrograph will start at the emergency-spillway-crest elevation. For a reservoir that includes a flood-pool, the routings will start at the elevation of the water surface that would exist after 10 days of drawdown through the flood-pool spillway from the design surface elevation of the flood-pool (FSM 7532.23).

Earthfill and Rockfill Dams

1. Top Width. For dams up to 15 feet in height, the top width will be not less than 10 feet. For dams from 15 feet to 90 feet in height, the top width will be not less than:

$$W = \frac{H + 35}{5}$$

Where W = Top width in feet
H = Maximum height of dam in feet

For dams over 90 feet in height, the top width will be not less than 25 feet.

2. Embankment Cross-Section. The fill zoning plan and the cross-sectional shape of the dam will be designed to ensure that the dam and its foundation will remain stable under any condition of loading and internal seepage that may reasonably be expected to develop during the life of the structure.

a. Stability analyses and settlement analyses of high-hazard and moderate-hazard dams and low-hazard dams over 25 feet high will be:

(1) Performed by methods conforming to accepted engineering practice.

(2) Based on realistic assumptions of applied conditions.

(3) Based on data obtained from competent investigations and the testing of representative samples of materials (FSM 7523).

b. Small, low-hazard dams may be designed by use of:

(1) Data from soil classification tests.

(2) Empirical design methods, such as Tables 12, 13, 15, and 16, Chapter V, Design of Small Dams, Bureau of Reclamation.

3. Internal Drainage

a. The design should include such embankment drains and foundation drains as are needed to:

(1) Prevent the uncontrolled emergence of water on the downstream slope of the dam.

(2) Reduce or neutralize seepage pressures to prevent failure by piping or heaving.

(3) Reduce pore pressures in confined foundation strata.

(4) Prevent saturation of zones where sheer strength is crucial to the stability of the structure.

(5) Ensure safe interception and disposal of water from zones that are susceptible to cracking induced by differential settlement.

b. When embankments or foundations contain materials that are susceptible to internal erosion or cracking caused by settlement, drainage filters should be provided at all critical discharge faces.

c. Where adequate quantities of free draining, coarse materials are available, internal drainage needs may often be met by zoning of fill within the dam. When suitable drain fill materials are not available near the site:

(1) For low-hazard dams, drains may be waived so long as the design risk is acceptable and accounted for in the maintenance plan.

(2) For all other classes of dams, suitable materials must be imported.

4. Erosion Control. When the outer slopes consist of erodible materials, measures will be applied to prevent erosion by rainfall, wind, or waves. In suitable climates, the downstream slope and the upstream slope above normal pool level should be planted to grass soon after construction. When the climate or fill materials will not support grass, or when grass protection is not adequate, slopes must be protected by berms or riprap facing.

a. Berms used to reduce erosion will:

(1) Have minimum width of 8 feet.

(2) Be placed at vertical intervals of not more than 40 feet.

b. The upstream slope will be protected from wave action throughout the full range of the conservation pool plus normal height of wave runup. Properly designed riprap or soil-cement slope protection is required for this purpose. For single purpose flood-retarding dams, wave protection may be provided by incorporating either of the following:

(1) A berm on the upstream slope located not more than 1 foot below the elevation of the flood-pool spillway crest, gently sloping (not greater than 10 percent) away from the dam, and planted to appropriate water-tolerant vegetation.

(2) Rock riprap or soil-cement protection throughout at least the range of normal wave runup or 5 feet, whichever is greater, above and below the flood-pool spillway crest elevation.

5. Foundation Treatment. The required foundation treatment will vary with the geology of the site, the service function of the structure, and the nature of downstream development. Foundation-treatment requirements will be established in the preliminary design phase, subject to change when conditions are exposed during construction. As a minimum, the following criteria will be applied in the area occupied by the dam:

a. Channel banks steeper than three horizontal to one vertical will be shaped to at least three to one.

b. Abrupt discontinuities, such as steep rock outcrops or erosion remnants, will be reduced or removed.

c. Where conduits cross the core trench, the sideslopes of the core trench will be flattened to at least three horizontal to one vertical.

d. The amount of excavation and backfill under conduits will be limited to that required to remove topsoil, roots, or other deleterious matter and to provide proper grade. Sideslopes of excavations for conduits should not be steeper than three horizontal to one vertical.

Concrete Dams. The design of concrete dams will conform to accepted engineering practice. Acceptable practice for small concrete gravity dams is well summarized in Chapter VII, Design of Small Dams, Bureau of Reclamation.

Outlet Conduit

General Criteria. The following criteria apply to all closed conduits located in or under earth dams or earth-and-rock dams.

Materials. Conduits located in or under earth dams or earth-and-rock dams must be durable for at least the expected life of the dam. For all moderate- or high-hazard dams and all low-hazard dams over 25 feet in height, conduits must be built of cast-in-place reinforced concrete, reinforced concrete pipe, ductile iron pipe, or steel pipe. For low-hazard dams up to (and including) 25 feet in height, conduits may be built of corrugated metal pipe at the discretion of the Regional Engineer.

1. Reinforced concrete pipe must conform to one of (1) American Water Works Association (AWWA) specification C-300, (2) AWWA specification C-301, (3) AWWA specification C-302, or (4) ASTM designation C-361. For conduits on yielding foundations, the pipe should be fitted with steel joint rings.

2. Ductile iron pipe must conform to Federal specification WW-P-421c.

3. Steel pipe must conform to either Federal specification WW-P-406 or ASTM designation A53, A135, A139, or A134. The pipe must be either (1) coated and wrapped in the manner specified in AWWA standard C-203, or (2) coated with a coal tar-epoxy paint similar to paint system I, SCS construction specification 82. For conduits on compressible foundations, the pipe should be either

jointed with rubber-gasketed, bell-and-spigot joints or fitted with watertight slidable couplings similar to Dresser couplings.

4. Corrugated metal pipe shall be either (1) zinc-coated iron or steel corrugated pipe conforming to interim Federal specification WW-P-00405, or (2) aluminum corrugated pipe conforming to Federal specification WW-P-402. The pipe should be fitted with watertight connecting bands or couplings.

The outlet shall be of the size necessary to satisfy downstream release requirements and capable of draining the reservoir to the elevation of the outlet within the time period specified by the engineering approving office, but the minimum inside outlet dimension shall not be less than 24 inches, unless potential significant downstream resource damage can be demonstrated.

Metal pipe used for high-hazard dams must be concrete encased. Otherwise, the outlet material shall be durable for the expected life of the dam. All joints shall be watertight to a capacity of at least twice the maximum operating head.

The outlet conduit shall be designed to safely support the external loadings. All outlet conduits in Class A and high-hazard Class B and Class C dams shall be embedded in a concrete cradle full length.

Structural Design

1. Rigid Conduits. Rigid conduits will be designed as positive projecting conduits. Loads will be computed by the Marsten-Spangler method.

For purposes of determining wall thickness, steel pipe and ductile iron pipe will be designed as rigid conduits.

Reinforced concrete pipe conduits will be designed according to the following criteria:

a. For pipe conforming to AWWA C-301, the three-edged bearing strength will be determined at the first 0.001 inch crack. The design safety factor will be at least one.

b. For pipe conforming to AWWA C-300, AWWA C-302 and ASTM C-361, the three-edged bearing strength will be determined at the first 0.01 inch crack. The design safety factor will be at least 1.33.

c. Systems of reinforcement that require special orientation of the pipe during placement, such as elliptical reinforcement or special sheer reinforcement, will not be allowed.

2. Flexible Conduits. Corrugated metal pipe will be designed by means of the load tables appended to Federal specifications WW-P-402 or WW-P-00405, as applicable.

Joints. Conduits placed on yielding foundations will be jointed as needed to allow adjustment to settlement and the associated longitudinal movements. Joints must be able to assume the ultimate adjustment without structural damage to the conduit or loss of watertightness. Special care should be taken in the

design of joints between the conduit and other structures, such as drop inlets, dry or wet wells, or outlet structures, to allow for the effects of differential settlement.

The required effective (watertight) length of the joint varies with the amount of rotation and axial pull induced by the settlement. Present methods for estimating required joint length are not entirely reliable. The method stated in Soil Conservation Service technical release 18 should give conservative results in most cases. Joint requirements should be estimated by this method. Estimates should be based on data from settlement analyses conforming to FSM 7533.2. When the computed joint extension exceeds 3 inches, the conduit should be relocated to a less vulnerable site.

In cradled pipe conduits, cradle joints should coincide with pipe joints. Jointing of concrete bedding is not required.

Antiseep Collars. All conduits will be provided with antiseep collars. Design will conform to the following criteria:

1. The number and size of collars will be adequate to ensure that the length of the additional seepage path along the surface of the collars is not less than the maximum net head of water that may act on the conduit.

2. Each collar will project at least 2 feet, but not more than 4 feet from the conduit, cradle, or bedding in any direction normal to the conduit. When the conduit is founded on sound, durable rock, the bottom of the collar will extend into the rock to a depth of 6 inches.

3. Collars will not be located in coarse, free-draining fill.

4. In the less pervious zone of the dam, collars should be evenly spaced along the conduit at intervals of not less than 15 feet. When the core zone is too narrow to accommodate enough collars to meet the criterion in Item 1, other protective measures may be required, such as; (1) filters around the conduit at the downstream edge of the core zone; or (2) mastic coating of the conduit in the core zone.

5. For conduits on yielding foundations, the joint between the collar and the conduit and cradle will be designed to allow independent movement of the collar and conduit and remain watertight.

Concrete antiseep collars are preferred to metal antiseep collars.

Testing. A conduit composed of reinforced concrete pipe conforming to AWWA specifications C-300 or C-301 need not be pressure-tested if; (1) it is installed in accordance with the manufacturer's instructions; and (2) the position of the gasket in each joint is checked around the entire circumference of the pipe by means of a metal feeler gage. For all moderate-or high-hazard dams and low-hazard dams over 25 feet in height, all other types of conduits will be water tested, prior to backfilling, at an internal pressure equal to at least the maximum operating pressure. Testing of conduits in low-hazard dams 25 feet in height or lower may be required at the discretion of the Regional Engineer.

Vibration Dampener. To prevent excessive and destructive vibration, a concrete cradle or a concrete structure which encircles the outlet pipe at the point of emergence from the downstream fill is recommended.

Foundations for Outlet Conduit. Whenever feasible, concrete or concrete-encased outlet conduits shall be carried to competent rock foundations. Insofar as possible, the foundations shall be placed on material of uniform character. Every effort shall be made to avoid conduit settlement and compressible foundations. All conduit connections to wet wells or other vertical shaft structures shall be designed to accommodate the conditions which may cause differential settlement.

Compaction Around Outlet Pipes. In order to reduce percolation of water along outlet pipes to a minimum, foundation preparation for, and compaction around, outlet pipes must be equivalent to foundation preparation for the dam and to compaction density of the impervious earthfill. Adequate provisions must be made to hold the pipe firmly in place during the compaction of the backfill material.

Gated Outlets. All dams except low-hazard Class B, Class C, and Class D dams must contain reservoir drainage outlets. The outlet must be able to drain at least two-thirds of the volume of the conservation pool.

The required size will depend on needs of downstream water users or the maximum drawdown time required by State or other regulations. For dams 25 feet in height, or higher, the inside diameter of the outlet will be at least 24 inches.

A control gate or valve must be installed at the upstream end of each outlet conduit, except spillways. Gates installed in wet or dry wells will fulfill this requirement so long as they are located upstream from the point where the conduit exists from the core of the dam a distance equal to half of the maximum water head on the conduit. Other control valves may be provided on the outlet at points downstream from the dam.

Gates, valves, and operators shall be of the size and design required to; (1) withstand the maximum water pressures, and (2) operate freely when acted on by the design seating or unseating pressures. They must be built of materials capable of withstanding the rigors of the exposure conditions.

When a slide gate is used, a vent pipe must be installed in the conduit just downstream from the gate. The size of the vent must be consistent with the size of gate and operating head.

Inclined gate stems are to be protected from ice or floating debris and shall be installed in oil-filled galvanized pipe. When gate-stem splices are made with machine bolts, the inside diameter of the pipe shall be at least 2 inches larger than the diameter of the gate stem. Smaller diameter pipe may be used provided the gate-stem splice is made with rivets or pins in lieu of machine bolts.

The gate-lift mechanism shall be located for accessibility.

Gates, valves, and operators must be protected from damage by ice or floating debris.

Stability Analysis. All earthfill dams which are classed as high-hazard Class A, Class B, or Class C will have a stability analysis computed. The preferred methods will be the so called "Standard Method of Slices" or the "Modified Swedish" (ref: Earth and Rockfill Dams - Page 340). In event other methods are used to determine the factor of safety, they shall be detailed and referenced in order that the factor of safety can be checked. The minimum allowable safety factor for any dam shall be 1.5.

An evaluation of earthquake potential shall be made for each structure, and the design criteria for the earthquake established. In each case, a determination of the need for analyses that include earthquake forces should be made on the basis of factors such as (a) hazard and risk factors, (b) size of the dam and reservoir, (c) the potential ground motion at the site, (d) site geology, and (e) type of structure. Where a determination is made that earthquake forces do not have to be considered, the determination should be documented.

Slope Protection. High embankments are susceptible to erosion from runoff of rainfall on the faces of the dam and from wave action. Insofar as practicable, the downstream slope and freeboard slope of the upstream face should be seeded to grass immediately upon completion of construction. Where vegetative methods are not considered adequate protection, berms or riprap facing shall be provided in the construction.

If berms are used to reduce erosion by runoff, they shall have a minimum width of 8 feet and shall be constructed on the face of the embankment at approximate vertical intervals of 40 feet.

Riprap or a gravel blanket may be used to prevent erosion by runoff on the face of the embankment in lieu of berms, and to prevent erosion from wave action on the upstream face. The manner of constructing the blanket facing will depend on available material and specific site conditions.

Recommended design criteria for slope protection against wave action follows:

The thickness of riprap for the main embankment of earth dams should be based on the wave heights computed for determing freeboard requirements. Based on these computed wave heights, riprap requirements for the embankement can be selected from the following table:

Computed wave height (feet)	Riprap Thickness (inches)	Maximum rock size (pounds)	Filter thickness 1/ (inches)
0 to 2	12	200	6
2 to 4	18	500	6
4 to 6	24	1,500	9
6 to 8	30	2,500	9
8 to 10	36	4,000	12

1/ Crushed rock or natural gravel graded from 3/16 inch to 3-1/2 inches.

The required riprap thickness may be decreased in proportion to the fetch for areas on the abutments of main structures or saddle dikes protected by ridges extending into the reservoir, shoal water, islands, or other topographic features which decrease the effective open water fetch. The thickness may also be decreased on flood control reservoirs where the water surface is fluctuating over a wide range of levels and is not maintained at one elevation for prolonged periods of time. As a minimum requirement, a thickness of 12 inches of a well graded quarry-run riprap with maximum weight of approximately 150 pounds for single pieces should be specified. For reservoirs having conservation pools, the riprap need extend only 5 feet, measured vertically, below the conservation pool level. Slopes flatter than one to five do not require the degree of protection necessary for steeper slopes, and the riprap may be decreased in thickness or quality in such areas.

Railroad and highway embankments adjacent to the main dam and subject to similar wave action should be protected to the same degree as the main dam. Along the reservoir shores, protection may be decreased in proportion to the fetch. In general, protection should be provided only for exposed portions of the embankments.

Open-Channel Spillways

Definitions

1. Control Section. In an open channel spillway, that section where accelerated flow passes through critical depth.

2. Inlet Channel. The part of the spillway upstream from the control section.

3. Exit Channel. The part of the spillway downstream from the control section.

Hydraulic Design. Spillways may be designed either for subcritical flow throughout or for supercritical flow in the exit channel. Supercritical flow in the exit channel is preferred. Spillways should conform to the criteria for channel design set forth in FSM 7540.

For spillways designed for subcritical flow throughout, the relationship between reservoir stage and the spillway discharge must be determined by computing the water surface profile throughout the entire spillway.

For spillways designed for supercritical flow in the exit channel, the relationship between the reservoir stage and the spillway discharge must be determined by computing the specific energy head at the control section and head losses in the inlet channel. The design of such spillways should conform to the following guides:

1. For a distance upstream from the control section at least equal to three times the critical depth of the freeboard discharge:

a. The centerline of the inlet channel must be straight and normal to the control section.

b. The sides of the channel must be straight and parallel.

c. No obstructions, such as bridge piers, can be placed in the channel.

2. The exit channel should:

a. Be normal to the control section at its upstream end.

b. Be straight and uniform to a point downstream from the control section where bank failure will not allow water to spill onto the embankment.

c. Have a grade steeper than critical slope for all flows equal to or greater than 25 percent of the design discharge.

Confirmation (by hydraulic model studies) of the design of a spillway intended to convey supercritical flow should be considered when the design cannot be made to conform to the above stated guides. The decision of whether or not model studies are required should be based on estimates of damage that could occur if the exit channel does not properly confine the spillway flow.

Emergency Spillways

1. A closed conduit may be used as an emergency spillway if:

a. The inlet is a type that will not clog with trash or floating debris. The SCS covered-top, drop-inlet riser is a good example.

b. All elbows and curves are designed to pass debris of a size that will pass through the trash guard.

c. The conduit has a cross-sectional area of at least 20 square feet.

2. A single conduit may be fitted to serve as both the emergency spillway and another type of outlet by use of a two-stage inlet or other multiple intake design.

3. Hydraulic and structural design should conform to the criteria set for flood-pool spillways.

The emergency spillway must be able to pass the design discharge without erosion damage to the crest of the spillway. When the design velocity cannot be kept to a nonerosive value, lining of the spillway will be required.

The duration of snowmelt flow may also affect decisions on spillway lining requirements. The snowmelt runoff should be routed through the reservoir for the purpose of estimating probable duration of flow through the spillway.

Flood-Pool Spillways. Spillways extending through or under a dam should conform to the criteria in FSM 7535.1 and to the following requirements:

1. The hydraulic design of drop-inlet spillways should conform to the criteria and procedures contained in any one of the following:

a. Technical Release 29, Engineering Division, Soil Conservation Service, United States Department of Agriculture.

b. Chapter VIII, Design of Small Dams, Bureau of Reclamation, United States Department of the Interior.

c. Technical Paper No. 12, Series B, St. Anthony Falls Hydraulic Laboratory, University of Minnesota.

2. The hydraulic design of hood inlet spillways should conform to the criteria and procedures contained in either of the following:

a. Technical Release No. 3, Engineering Division, Soil Conservation Service, United States Department of Agriculture.

b. Bulletin No. 35, Engineering Experiment Station, Oregon State University.

3. The spillway conduit will be cambered to ensure free drainage to the outlet at the time it is built and also after the foundation has been compressed by the weight of the dam.

4. Conduits should be straight when viewed in plan. When curves are needed, they should be as slight as possible. Curve radius should be long enough to ensure passage of debris.

5. Conduit diameter will be at least 24 inches. Larger sizes are preferred to ensure passage of debris and access for inspection and repair.

6. When orifice control of discharge is required, a vent pipe must be installed in the conduit just downstream from the orifice plate. The vent must extend at least to the elevation of the flood-pool. The size of the vent must be consistent with the size of the conduit and the operating head.

7. Closed conduit spillways designed for pressure flow will be fitted with effective antivortex devices.

8. Trash guards will be designed to prevent clogging of the spillway at any point. The velocity of the flow through the clean trash guard should be not greater than 2 feet per second under the lesser of the following conditions:

a. When the water surface is 5 feet above the top of the guard.

b. When the water surface is at the elevation of the emergency spillway crest.

9. The criteria and procedures contained in Section 11, Engineering Handbook, Soil Conservation Service, United States Department of Agriculture. The design of box-inlet-drop spillways should conform to the criteria and procedures contained in Agriculture Handbook 301, United States Department of Agriculture.

A reinforced concrete chute may be used as a flood-pool spillway. When so used, the chute should conform to the following criteria:

The hydraulic design of chutes should conform to the criteria and procedures contained in either of the following:

1. Section 14, Engineering Handbook, Soil Conservation Service, United States Department of Agriculture.

2. Chapter VIII, Design of Small Dams, Bureau of Reclamation, United States Department of the Interior.

3. The inlet and channel sections must be designed to contain the discharge induced by the freeboard reservoir stage.

4. The energy dissipator must be designed to contain a volume of flow at least equal to the discharge induced by the design reservoir stage.

For the purpose of proportioning spillways, the design surface elevation of the flood-pool is defined as the highest reservoir water surface determined by routing the flood-pool hydrograph through the reservoir and flood-pool spillway.

The size of the flood-pool may be governed by either of the following factors:

1. The required degree of downstream flood protection selected by economic studies of costs and benefits.

2. A limit to the frequency of use of the emergency spillway arbitrarily selected to protect the spillway.

Energy Dissipators. The choice of the type of energy dissipator to be used on a given structure should be based on a careful consideration of all site and flow conditions that may affect the operation of the dissipator. The following general criteria should be observed:

1. Structures depending on plunge-pool action for energy dissipation, such as cantilever outlets or flip buckets, may be installed at sites where the pool:

a. Does not create a piping hazard in the foundation of the structure.

b. Is compatible with other site developments.

c. Does not conflict with public health vector control regulations.

They may be installed without preexcavated plunge-pools in sites having deep soil profiles consisting of moderately erodible materials. They should not be sited in extremely erodible soils, such as fine sands or silty-fine sands. In very cohesive soils or where excessive lateral erosion may be induced, such as where a shallow soil profile is underlain by rock or very cohesive soil, the plunge-pool should be preexcavated to adequate depth and extent. In all cases,

the invert elevation of the downstream end of the cantilever should be at least 1 foot higher than the tailwater elevation in the outlet channel at maximum discharge.

2. Hydraulic jump basins should be used only when control of tailwater depth is reasonably assured. In cases where tailwater control is not assured by natural channel conditions, other methods should be applied, such as:

a. The installation of a tailwater control structure, such as a drop spillway, downstream from the jump structure.

b. The use of an impact basin instead of a jump basin.

c. Where excessive tailwater depths will develop, the use of a roller bucket instead of a jump basin.

3. Impact basins should be used only when positive measures are taken to prevent large debris from entering the conduit.

Hydraulic Jump Basins. The hydraulic design of hydraulic jump basins should conform to the criteria and procedures contained in either of the following:

1. Agriculture Handbook 156, United States Department of Agriculture.

2. Chapter VIII, Design of Small Dams, Bureau of Reclamation, United States Department of the Interior.

Impact Basins. The hydraulic design of impact basins should generally conform to the criteria contained in either of the following:

1. Chapter VIII, Design of Small Dams, Bureau of Reclamation, United States Department of the Interior.

2. Journal of the Hydraulics Division, No. HY5, October 1957, Paper 1406, American Society of Civil Engineers.

Protection from Debris. In forested watersheds, provisions must be made to prevent debris and logs from jamming the spillway entrance. Floating booms or float-cable barriers are effective for this purpose. In recreation impoundments, such booms or barriers should be clearly flagged or otherwise marked to prevent boating accidents.

Spillway Control. No flashboards, gates, or other water level control devices will be installed in the emergency spillway above the computed emergency spillway crest elevation, except under one of the following conditions:

1. When hydrologic studies and structural considerations show that they may be safely used at certain seasons (other than the predictable flood season), they are of types that are operable (or removable) under any condition of flow through the spillway, and operating plans ensure their proper use.

2. When a properly trained, full-time operating staff is maintained at the dam and the water level control devices are of types that are operable under all conditions of flow through the spillway.

3. When the water control devices are of an automatically collapsing type and their use will not endanger the dam or hazard downstream life or property.

Design Standards and Criteria for Channels. This chapter presents design criteria for Class A and Class B artificial channels. Many of the criteria should be applied also to Class C channels.

Layout and Proportioning

Layout. Where the best alignment of the channel is not obvious, various layouts should be studied to find the location of least cost or least interference with other land use. The channel should follow the natural drainage pattern as closely as is practicable except in either of the following cases:

1. Where studies show that significantly less total cost will result from deviations from the natural drainage pattern.

2. Where the purpose of the channel requires that it depart from the natural drainage pattern.

Interception ditches should be provided on both sides of the channel throughout the length of the project where needed to control local drainage. Where the land slopes toward the channel, spoil banks not topped with a roadway should be sloped toward the land side to form a drainage ditch. The top of the ditchbank thus formed should be at least 12 inches above the ground surface. Ditches should be graded so as to drain into the channel only through control structures.

Proportioning. The proportioning of lined channels should be based on the determination of the most economical and feasible combination of grade and cross-section. The proportioning of earth channels and the estimation of the capabilities of natural channels should be based on full consideration of:

1. The erodibility of materials in banks and stream bottom, bank stability, suspended sediment load, bedload, and natural stream morphology.

2. The effects on the natural stream regimen of changes in alignment, grade, suspended load, quantity of flow, and duration of flow.

Hydraulic Design

Notations. For the purposes of this handbook, the following notations are used:

d_n = depth of normal flow

F = freeboard

H_e = specific energy head

R_c = radius of main circular curve

R_t = radius of easement circular curve

s_c = critical slope for design discharge

s_o = slope of channel bottom

Coefficient of Roughness. The roughness of an unlined channel varies with the change in condition of the sides and bottom. Changes in roughness affect the velocity of flow in the channel at any given stage (or, conversely, affect the depth of flow for any given discharge). The designer must consider the effects of changes in roughness on both the stability of the channel and the capacity of the channel.

In the design of earth channels and spillways, the upper and lower limiting values of the coefficient of roughness, n, must be estimated. The limits will vary with such factors as; (1) soil types, (2) vegetation types, (3) climate, (4) concept of operations, and (5) maintenance capabilities. The lower value of "n" should be used in flow computations intended to analyze channel stability. The upper value of "n" should be used in flow computations intended to analyze channel capacity.

Lined channels should be designed for the value of "n" appropriate to; (1) materials used, (2) the proposed economic life, and (3) the maintenance plan.

Curves. Changes in channel alignment should be designed as simple circular curves, compound curves, or simple curves with spiral easements. Compound curves or spiral easements should be used:

1. When necessary to limit the superelevation of the water surface.

2. In channels conveying flows at supercritical velocities when two or more curves in series are separated by tangents less than 1,000 feet long.

Compound curves should consist of three sections; a main (or central) curve, an approach curve, and a terminal curve. The approach curve and the terminal curve each should have a radius (R_t) equal to twice the radius (R_c) of the main curve and should have a length adequate to prevent the creation of standing waves downstream from the curve.

Spiral easement curves should be designed so that the maximum wave height on the outside wall of the channel at the point of curvature of the main curve is equal to or less than one-half of the computed superelevation in the central curve.

The superelevation of the water surface (above normal depth of flow) at curves should not exceed 10 percent of the water surface width or 1 foot, whichever is less.

Freeboard. Freeboard, above the computed depth of normal flow plus superelevation, should be provided in accordance with the following criteria:

1. Rectangular section (Minimum freeboard).

   a. When $s_o < 0.7\ s_c$: $F = 0.1\ H_e$

b. When $s_o > 1.35\ s_c$: $F = 0.2d$

c. When $0.7\ s_c < s_o < 1.35\ s_c$: $F = 0.1\ H_e$ plus the computed wave height.

2. Trapezoidal section (Minimum freeboard).

a. When $s_o < 0.7\ s_c$: $F = 0.2\ H_e$

b. When $s_o > 1.35\ s_c$: $F = 0.25\ d_n$

c. Whe $0.7\ s_c < s_o < 1.35\ s_c$: Avoid the use of trapezoidal section.

Transitions. Transitions should be provided at all points where a change in the size or shape of the channel occurs. Such transitions should be designed to provide a gradual change in flow conditions without excessive turbulence or loss of head. Unless determined by hydraulic model studies, the length of a transition in a channel conveying flows at supercritical velocities should be such that the angle between the axis of the transition and a straight line joining the flow lines at the two ends of the transition does not exceed 12.5 degrees.

Obstructions. Head losses caused by obstructions, such as bridge piers, should be computed by the momentum method.

Junctions. The junction of two or more channels should be designed to allow the confluence of the stream without excessive turbulence or loss of head. In general the design:

1. Should ensure that the directions of flow in the joining streams at the point of confluence are as nearly parallel as possible to the direction of flow in the exit channel below the point of confluence.

2. Should be analyzed by the momentum method.

The final design of junctions of trapezoidal channels conveying flows at supercritical velocities should be either based on or confirmed by hydraulic-model studies. The final design of junctions of rectangular channels conveying flows at supercritical velocities and that are particularly complex or that are particularly crucial to the successful functioning of the channel system should be based on or confirmed by hydraulic-model studies.

Control Structures. Control structures should be provided where needed for grade control, water-stage control, or energy dissipation (FSM 7550).

Unless otherwise approved:

1. Irrigation supply channels should be provided with headworks capable of controlling and completely cutting off the flows entering the channels.

2. Lined floodway channels should be provided with headworks designed to provide positive control of the flows entering the channels. Wherever a lined channel discharges into an earth channel, one of the following should be provided:

a. A suitable energy dissipator (FSM 7550).

b. The earth channel revetted to the point downstream where the velocity of flow is reduced to that tolerable by the unprotected earth materials.

Structural Design of Concrete Channel Linings. The following general criteria should be observed in the design of channel linings:

1. Expansion joints should be provided:

a. At the points of juncture between structures and pavements or channel linings.

b. At such other points in walls and slabs as may be needed to prevent structural damage from expansion or other relative movements of structural elements.

2. Reinforcing should not extend through expansion joints; smooth steel dowels may extend through joints if they are wrapped or coated on one side of the joint to prevent bonding with the concrete.

3. Cutoff walls extending into the foundation and banks should be provided at the inlet and outlet terminals.

4. For channels conveying flows at supercritical velocities:

a. Joints in linings should be made watertight by incorporation of adequate water seals or waterstops.

b. For thin-section trapezoidal linings, cutoff walls should be provided at expansion joints and at intervals of not more than 1,000 feet.

c. Linings should be reinforced both longitudinally and transversely.

d. Outlets of underdrains should be located above the elevation of the design water surface.

Design Criteria for Low-Hazard Class C and Class D Projects

1. Design Features - Low-hazard Class C and Class D Dams

a. Freeboard. Freeboard will be a minimum of 2 feet.

b. Flashboards. No flashboards will be approved.

c. Spillway.

(1) Capacity. The spillway capacity will be determined by maximum flood flows. Flood flows will be determined on the basis of maximum stream flow records. If no records are available, the flood flow formula and method will be used as outlined in Part B, page 27, and Appendix A, page 413, of Design of Small Dams.

2. Erosion Protection. Spillways shall be protected against damaging erosion by one or more of the following methods:

a. Locate in erosion-resistant material.

b. Limit velocities to erosion-safe values.

c. Use energy-dissipating devices.

d. Channel lining.

3. Layout of Spillway. Spillways shall be free of abrupt changes in alignment or grade, and designed to provide for disposal of flood flows as quickly and efficiently as is consistent with erosion-safe velocities. Lined sections will be protected by headwalls and aprons as required.

4. Outlets. Outlet pipes with control gates are usually necessary. The outlet conduit shall be designed to safely support the external loadings. The conduit shall be of sufficient capacity to satisfy downstream requirements, but the minimum inside diameter shall not be less than 24 inches.

5. Design Features - Class C Earthfill Dams

a. Top Width. The top width will be determined by the formula:

$$W = \frac{H + 35}{5}$$ with a minimum width of 7 feet.

b. Embankment Slopes. The upstream slope will be three horizontal to one vertical. Downstream slope, unless submerged, will be two horizontal to one vertical. Submerged downstream slope will be three horizontal to one vertical.

c. Selection of Embankment Material. Soil used in the embankment will be impervious or semi-impervious. In case of doubt, field or laboratory classifications will be determined in accordance with the Unified Soil Classification System.

d. Foundation. The area to be occupied by the dam embankment shall be cleared, stripped, and excavated to a sufficient depth to remove all unsuitable materials; such as, topsoil, rubbish, vegetable matter--including stumps and roots--and all other perishable and objectionable material.

e. Cutoff Wall. A cutoff wall at least 6 feet wide and composed of well-compacted, impervious backfill material will extend at least 5 feet into the in-place formation whenever practical.

The most effective and efficient structure will result if the completed design calculation, plans, and specifications are subject to an independent check. Regional Office personnel are available for review and comment on Class C designs. Report on low-hazard Class B and Class C dams will follow format for Class A and high-hazard Class B dams, using only the applicable items. Show correlations with all design standards.

Canals and Ditches. Design criteria, requirements for drawings and specifications, and report to accompany drawings for canals, ditches, and natural channels are included in this section.

Standards

1. Design Criteria. Design and construction of canals and ditches on National Forest land will be in accordance with accepted engineering practices and with applicable State and local laws and regulations.

a. Hydraulic Design. Gradient and cross-section of the channel shall permit transmission of water without erosion or deposition in the channel. Permissible design velocities will vary with soil type and channel treatment. Guides for permissible velocities are given in the following table:

Material	Maximum Velocities (ft. per sec.)
Fine sand, non-colloidal	1.50
Sandy loam, non-colloidal	1.75
Silt loam, non-colloidal	2.00
Alluvial silts, non-colloidal	2.00
Ordinary firm loam	2.50
Volcanic ash	2.50
Fine gravel	2.50
Siff clay, very colloidal	3.75
Graded, loam to cobbles, non-colloidal	3.75
Alluvial silts, colloidal	3.75
Graded, silt to cobbles, colloidal	4.00
Coarse gravel, non-colloidal	4.00
Cobbles and shingles	5.00
Shales and hardpans	6.00

b. Structures. The inlet structure shall be designed in such a way that the maximum amount of water which can be diverted into the canal or ditch does not exceed the design flow. Water from canals or ditches will not be discharged into unprotected slopes or side channels.

c. Embankment. The dimensions of the canal banks and the soils of which they are composed must assure stability under designed hydraulic conditions.

d. Freeboard. Freeboard shall be provided to ensure against overtopping or failure of the bank.

(2) Length of project: _____ feet

(3) Freeboard: _____ feet

(4) Estimated Cost: $_____

(5) Project Drawings: Drawing numbers _____

No. of sheets _____

Surveyed by _____

Date of survey _____

c. Design Data

(1) Lined Canal. Give type of lining material and show cross-section on plans.

(2) Unlined Canal. Soils through which the canal will be constructed will be classified by the Uniform Soil Classification System. Specify method used to determine classification. If field determination is used, give name and qualifications of person making tests. If laboratory analysis made, submit copy of results of laboratory tests.

(3) Hydraulic Data. Show method of computing capacity and assumptions made.

(4) Inlet Computations. Show basic computations for determining inlet capacity.

d. Construction

(1) Show date start of construction is anticipated.

(2) Show length of time to complete.

e. Water Right. Give evidence of water rights, if applicable.

f. Possible Damage in Case of Failure

(1) Give extent of possible land damage from erosion.

(2) Show potential for possible loss of life.

(3) Estimate damage to roads, bridges, buildings.

(4) List other property damage.

(5) Specify hazard classification.

e. Foundation. Canal subgrades and embankment foundation must be suitable to prevent excessive seepage or piping, high settlement, and slope stability.

2. Requirements for Plans and Specifications. For all moderate hazard and high-hazard projects, the title block on the plans will show the name of the design engineer, the initials of the engineer checking the design, the name and title of the approving engineer, and the signature of the owner or sponsor.

The plans and specifications will include all information needed for construction control of the project, and for review of its hydraulic and structural design. Plans will be easily readable, in English, and clearly legible. In addition to details of structural and mechanical features, they will include:

a. A vicinity map of the entire project.

b. Typical cross-sections showing the designed water level.

c. A profile of the canal with slopes and velocity at design flows listed at each different reach.

d. Details of the inlet, outlet, and other structures.

e. Design capacity and velocity of flow.

f. Roads, utility lines, etc., that will be affected.

3. Report to Accompany Plans for Class C Water Transmission Projects. The applicant will prepare a report to accompany the plans. The report will contain the following information:

Report to Accompany Plans

_____
(Name of Project)

a. Location and Purpose

(1) Location by legal description, County, State and nearest City.

(2) Accessibility - If an operation or maintenance road is to be included in the project, show location and design requirements.

(3) Purpose of project.

(4) Area where water will be used.

b. Summary of Design

(1) Canal capacity: _____ cfs

The following material is a sample set of plans showing pertinent categorical format. It is included to provide guidance, although your set of plans will be project-specific.

All signature blocks should include space for approvals by:

1. Responsible Engineer in charge of plans.

2. State Engineer.

3. Forest Service Engineer.

This sample plan is reduced for convenience. Standard acceptable size is 22" x 36".

WATERSHED PROTECTION AND FLOOD PREVENTION PROJECT

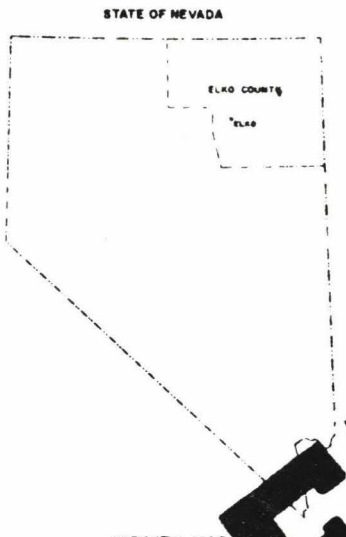
ELKO COUNTY NEVADA

PLANS FOR THE CONSTRUCTION

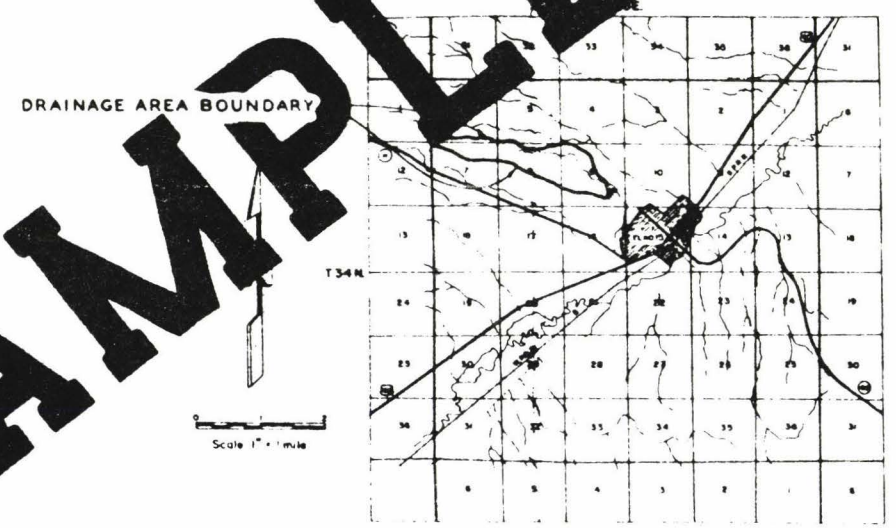
OF

EIGHT MILE CREEK DAM

EXAMPLE



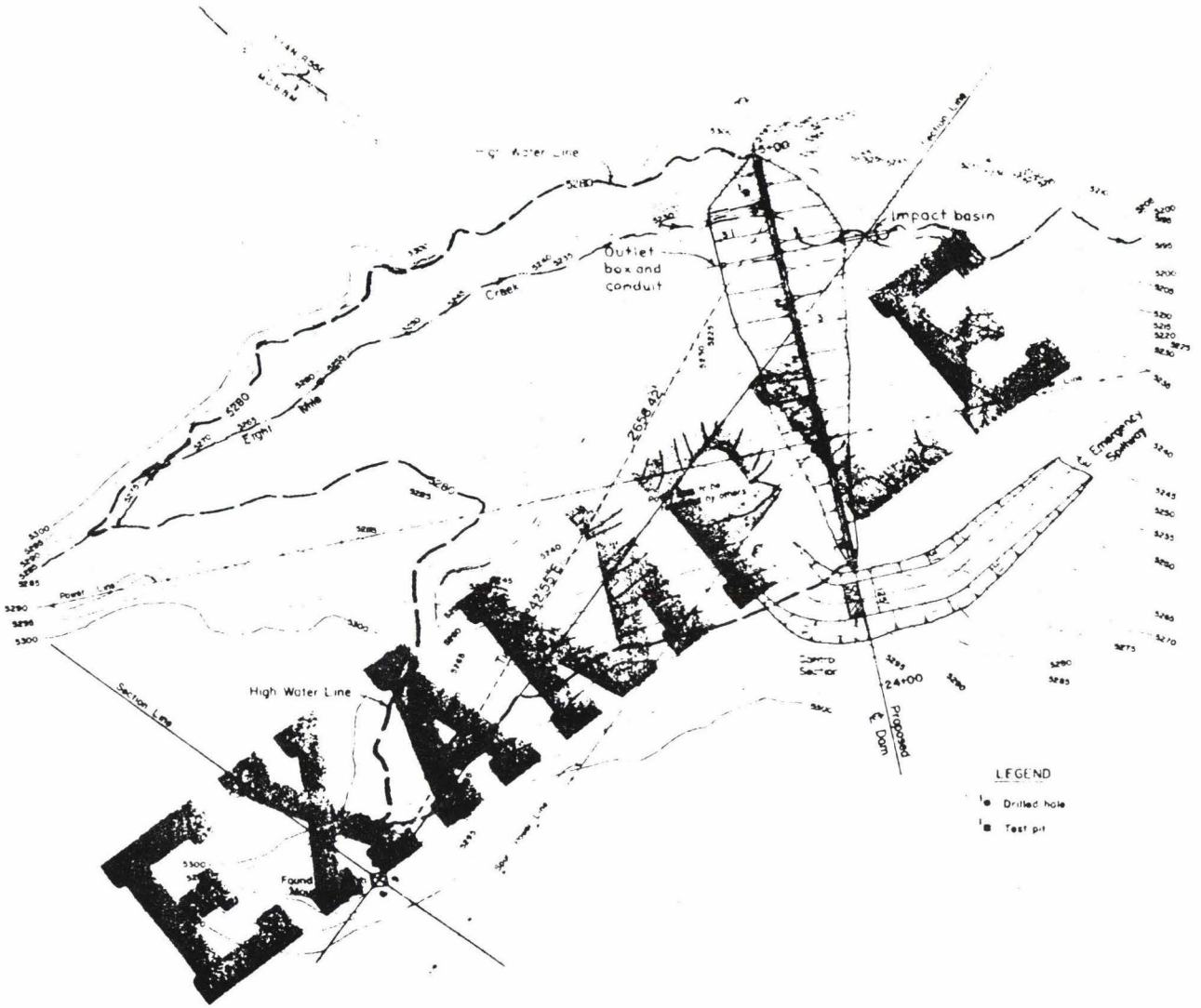
VICINITY MAP



DRAINAGE AREA BOUNDARY MAP

EIGHT MILE CREEK DAM
OF
JOHN Q. DOE
ON
EIGHT MILE CREEK
SECTION 14 T 36N, R 20W, M D B & M
DESIGNED BY John O Smith

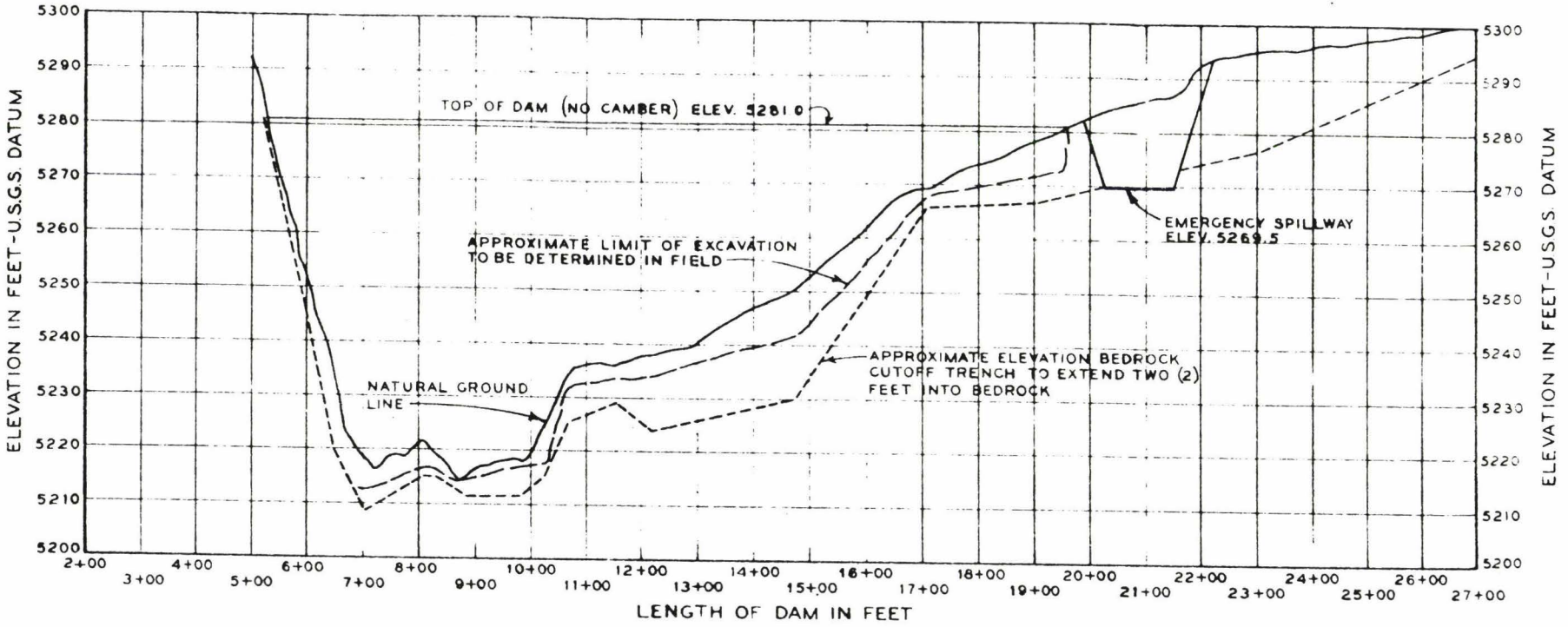
SHEET 1 OF 7 SHEETS



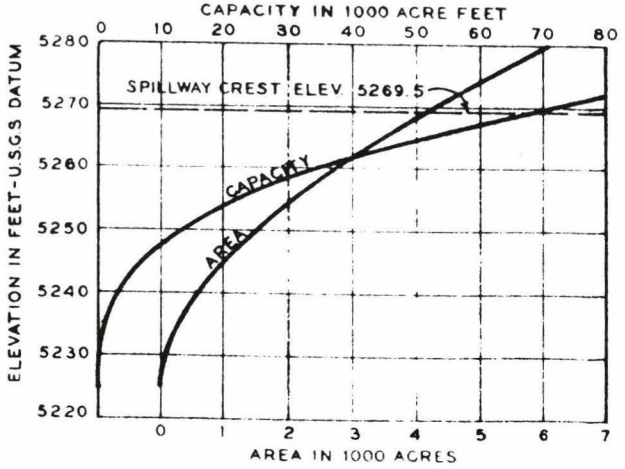
PLAN OF DAM

0 200 400 600
Scale in Feet

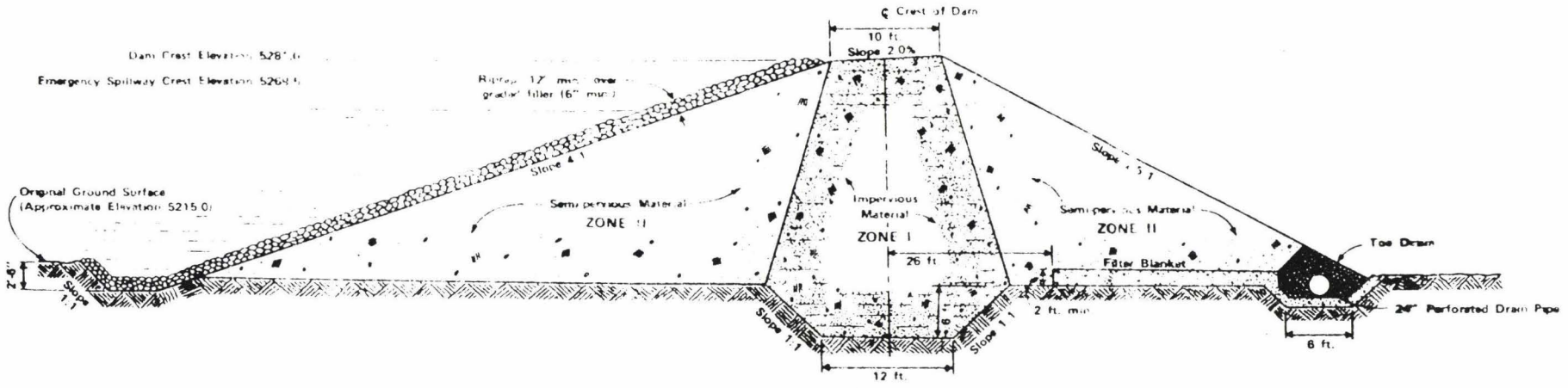
SHEET 2 OF 7 SHEETS



PROFILE ON AXIS OF DAM

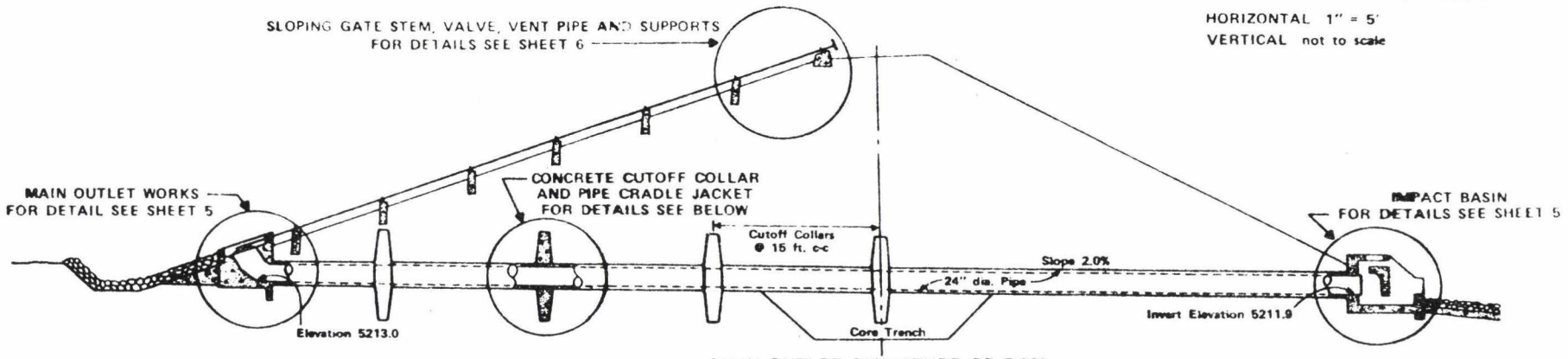


AREA & CAPACITY CURVES

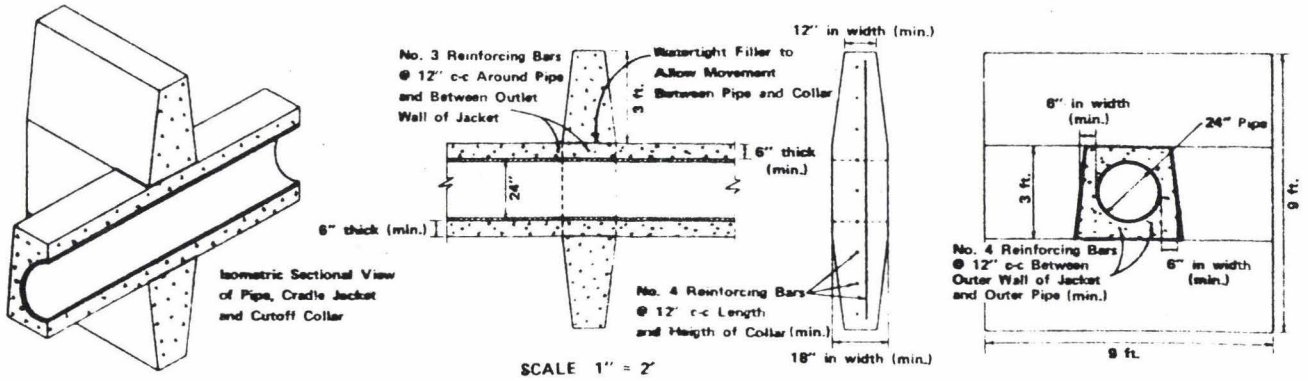


MAXIMUM SECTION OF DAM

SCALE FOR THE DRAWINGS ABOVE AND BELOW
HORIZONTAL 1" = 5'
VERTICAL not to scale



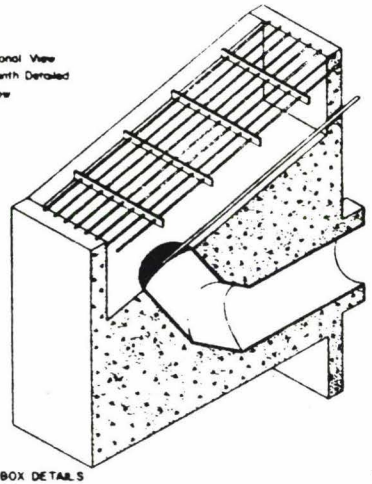
MAIN OUTLET STRUCTURE OF DAM



SCALE 1" = 2'

TYPICAL SECTIONS OF PIPE, CONCRETE CRADLE JACKET AND CUTOFF COLLAR

Isometric Sectional View of Outlet Box with Detailed Plan Views Below

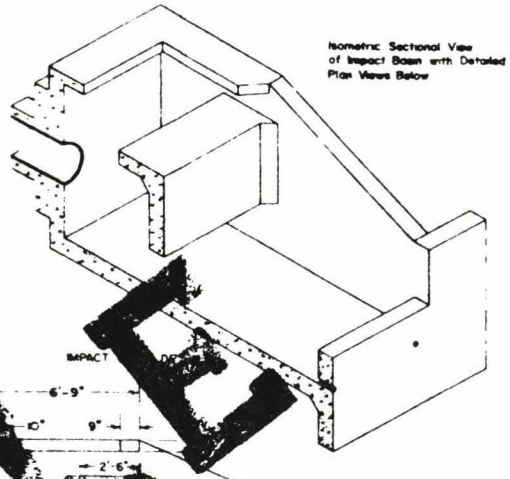


INLET BOX
(SHOWN ON THE LEFT)

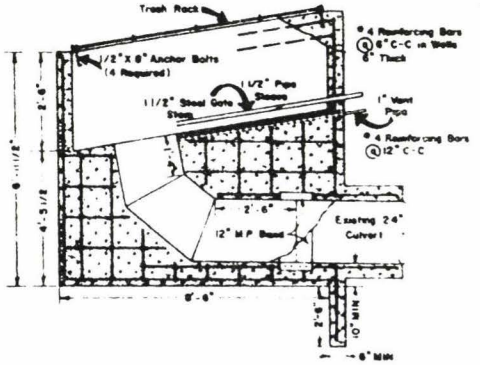
IMPACT BASIN
(SHOWN ON THE RIGHT)

STEEL GATE STEM, ADJUSTABLE GATE STEM GUIDE and GUIDE SUPPORT
(SHOWN AT THE BOTTOM)

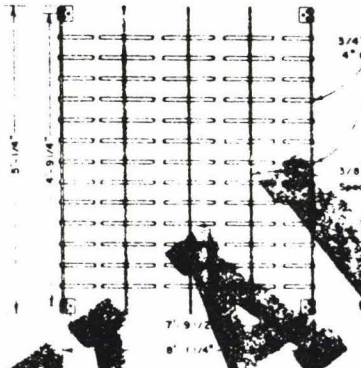
Isometric Sectional View of Impact Basin with Detailed Plan Views Below

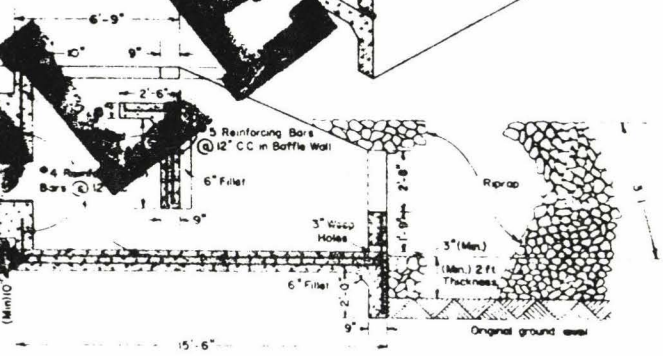


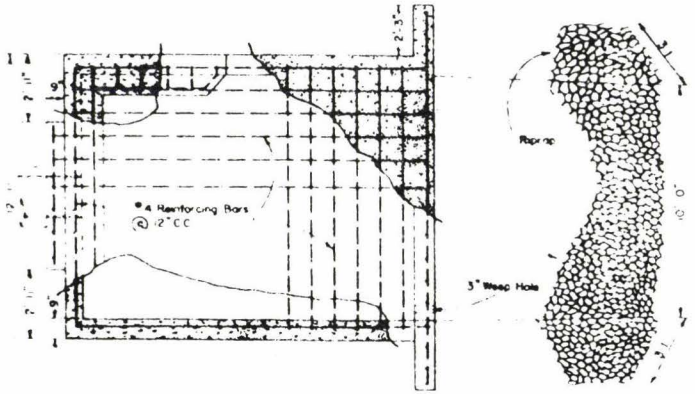
OUTLET BOX DETAILS



TRASH RACK DETAILS







ADJUSTABLE GATE STEM GUIDE AND SUPPORT DETAILS

Gate and gate controls are to be shown on separate sheets

EXAMINED

CROSS SECTION
EMERGENCY SPILLWAY

Station 3+00 - Slope = +0.010

CROSS SECTION
EMERGENCY SPILLWAY

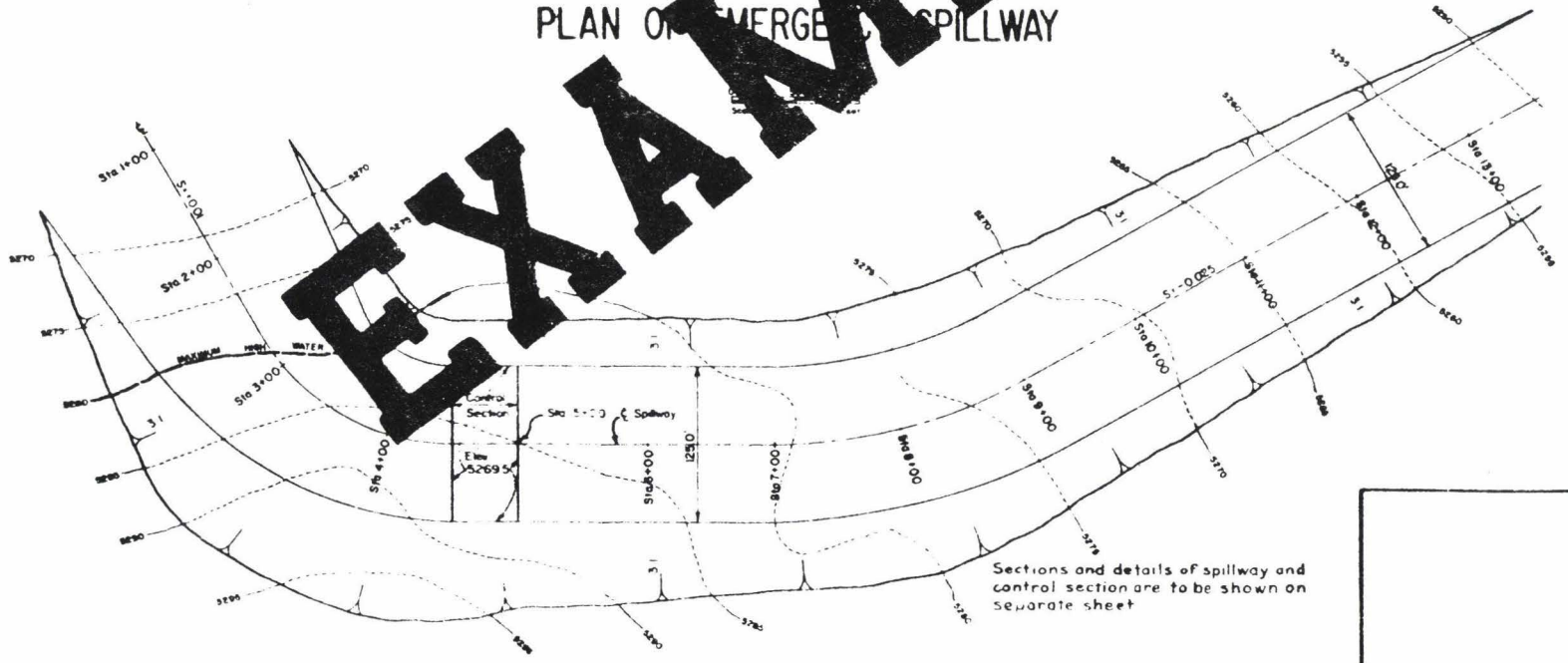
Station 5+00 - Slope = 0.000

CROSS SECTION
EMERGENCY SPILLWAY

Station 9+00 - Slope = -0.025

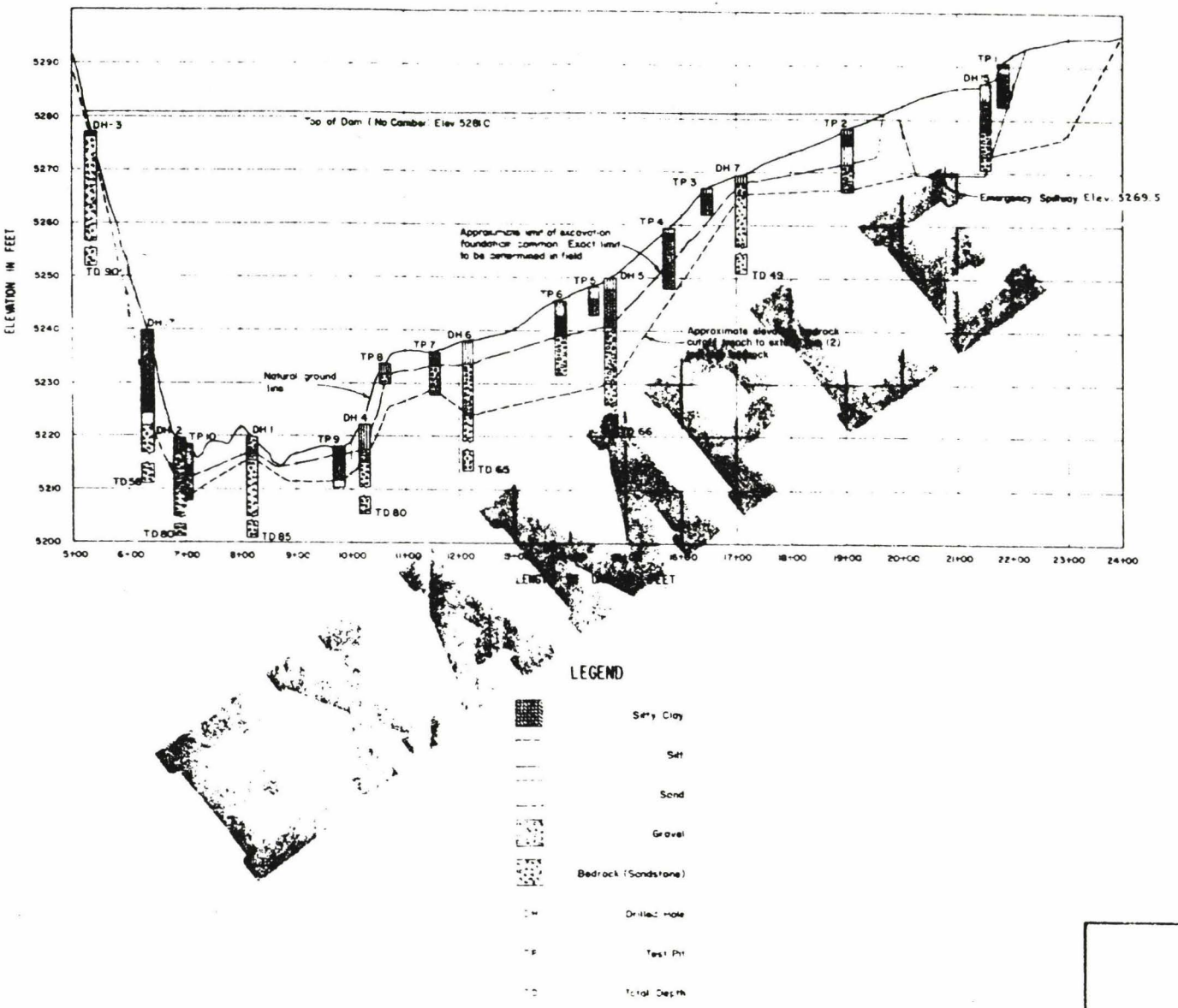
EXAMPLE

PLAN OF EMERGENCY SPILLWAY



Sections and details of spillway and control section are to be shown on separate sheet

CHANNEL PROFILE ON AXIS OF DAM & SOIL LOGS



SHEET 7 OF * SHEETS